A REVIEW OF RADAR REMOTE SENSING FOR TROPICAL FOREST MANAGEMENT*

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ABSTRACT

Tropical forests are one of the Earth's most valuable resources, from both economic and ecological perspectives. Their large areas and frequent cloud cover make them promising candidates for management strategies which incorporate satellite radar data. Optical satellite data, however, also should play an important role, provided that less frequent coverage is acceptable. In light of this situation, we have conducted an investigation into the potential contributions radar satellite data may make toward wise management of tropical forests. We have reviewed previous satellite and airborne studies using radar and, to a lesser extent, optical data in tropical forestry. The results indicate, for many tropical forestry applications, that radar satellite data should provide a valuable data source for reliable monitoring functions of use in forest management.

The decade of the 1990s will see several significant satellite synthetic aperture radar (SAR) systems in operation. All such systems are reviewed, particularly with respect to coverage, frequency and image parameters. The predominant frequency is C-band. Although showing promise in tropical forest applications, quadrature polarimetric satellite systems will not be operational until after the turn of the century.

Satellite radar experience to date suggests that several monitoring objectives would be well met using such data. However, our investigations have identified two important problem areas which must be addressed urgently: a dearth of C-band data of tropical forests upon which to base more critical assessments of satellite radar performance, and the lack of a data pricing policy for radar remote sensing data products which would underwrite and

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support the need to acquire large amounts of wide area data for global tropical forest monitoring as well as high-resolution data for more detailed management information.

INTRODUCTION

The purpose of this paper is to consider typical information requirements for tropical forest monitoring and to examine the contribution that microwave remote sensing systems (in conjunction with other readily available data sources) may make to the important issue of forest management.

Tropical forests are one of the Earth's most valuable resources. From an ecological perspective, they play a major role in the hydrological cycle and in recycling atmospheric carbon dioxide. They stabilize soil and prevent excess run-off of silt and dissolved substances into streams. Their effects on climate through energy and water exchange with the atmosphere are not well understood but are expected to be significant. Much of the Earth's species diversity is represented by the plants and animals which comprise tropical forest biomes.

The rate of destruction of tropical forests has been widely documented and publicized. 1/ 2/ 3/ 4/ 5/ 6/ For most tropical countries, deforestation has become a drain of an increasingly valuable resource. Local and overseas interests alike have overexploited forest resources. Failure to collect royalties, export taxes and related fees had led to a chronic undervaluation of tropical forest resources. 7/

While it is apparent that the improved management of tropical forests requires substantial economic, political, and institutional changes, it also requires additional information about the forests themselves and changes which are happening in and around them. Much of the additional information can be supplied by satellite and airborne remote sensing systems (with adequate field checking).

STUDIES WITH MICROWAVE DATA

The advantage of radar remote sensing in operating independently of solar illumination and in areas of persistent cloud cover, such as the tropics, was demonstrated in the successful completion of the first imaging radar mission over Darien Province of Panama in the late 1960s. 8/

Numerous studies of the application of radar remote sensing in the Tropics have been carried out since then. Most of the tropical experience with radar has been "on-the-job learning" as part of operational surveys, in contrast with temperate latitude studies, which have been generally of a formal research nature. A few reviews of the use of radar for forestry applications have been published. 9/ 10/ 11/

Airborne SAR and SLAR surveys

Airborne Synthetic Aperture Radar (SAR) and real aperture Side Looking

Airborne Radar (SLAR) imagery of tropical areas around the globe have been acquired during more than 50 major commercial reconnaissance surveys, employing mainly X-band SLAR and SAR systems with polarization and to some extent a Ka-band SLAR system with horizontal vertical (HV) polarizations. Regional and nationwide surveys in South-East Asia and Africa as well as Central and South America currently exceed more than 15 million km^2 in areal coverage. With the exception of more recent investigations employing digital SAR data, image analysis procedures have mainly relied on visual interpretation techniques. During the 1970s, most data sets were collected by the Westinghouse SLAR, the Motorola/MARS SLAR and the Goodyear/GEMS SAR systems. The data were optically correlated and processed on image film suitable for qualitative image analysis. The primary objective was the assessment of natural resource, terrain mapping and map revision, whereas in many instances the analysis of tropical vegetation was of secondary importance. 12/

The development of digital SAR imaging and processing technology by Canadian industry and the Environmental Research Institute of Michigan (ERIM) during the early 1980s resulted in advanced operational systems. Digital SAR data with a spatial resolution as good as six metres and offering high geometric and radiometric fidelity were used in computer assisted image analysis procedures, for the construction of image mosaics and in topographic mapping programmes. Since the mid-1980s, Intera Technologies of Calgary has employed airborne SAR systems in the Tropics for a variety of commercial forestry and land cover surveys, including those with a focus on natural vegetation. 13/

Regional and nationwide tropical vegetation surveys, primarily using X-HH data, have been reported by a number of investigators. Major vegetation formations and to some extent zones experiencing ecological transition and stress within the Tropics have been identified, including savannah, dense and open tropical forest and woodland mosaics. Difficulties were encountered in identifying specific formations in hilly or mountainous terrain. De Molina and Molina 14/ were able to map 30 different vegetation cover types in Colombia at a scale of 1:40,000. Areas of selective logging and differing tree crown densities were also identified.

There is further evidence that mangrove forest environments can be mapped accurately because of their generally strong radar backscatter compared to surrounding forest stands. 15/ 16/ Success was reported in discriminating primary and secondary forests and in mapping a variety of forest cover types, including mangrove/Nypa palm swamp, beach forest, peat swamp forest, hill dipterocarp forest, high scrub forest, tea tree and wallum cover, eucalyptus forest and mimosoid legume and palm forests. 17/ Their data source was high-quality black and white stereo prints made from X-Band digital SAR data with resolutions of 6 x 6 m and 6 x 12 m.

Plantation types which have been distinguished on airborne SAR imagery include palm and bananas 18/ and pine, eucalyptus, and rubber. 19/ 20/ Also, several studies indicate that forest disturbances can be detected and mapped. 21/ 22/ 23/ 24/

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To date, there has been only one airborne SAR mission over tropical forests including C-band. The Jet Propulsion Laboratory (JPL) aircraft, using C, L, and P-bands completed a series of flights over Belize in March 1990 from which prelinimary results are appearing. 25/ One value of these data is that it allows a direct comparison between these three wavelengths to tropical forest cover. Results show that image contrast in response to deforested/forested boundaries increases with wavelength, as expected.

There is a decrease in mean reflectivity at C-band with increasing incidence over the range of angles expected from RADARSAT, a phenomenon that may prove to be useful. Change in reflectivity with incidence angle is progressively less pronounced as wavelength increases. C-band data are not the best frequency for tropical forest monitoring. Based on the very limited data now available, it shows little contrast between undisturbed tropical forest and older deforested areas or dense plantations. The limits and strengths of the C-band data in these and other applications require further investigation.

The JPL experiment concentrated on the new dimension of quadrature polarimetry in tropical forest applications. Using this feature, scattering from the aerial foliage, the standing timber, and the surface beneath the forest may be differentiated. 26/ 27/ the P-band shows the greatest power in expressing these three requirements through polarimetry. It holds promise for future missions that have radars capable of delivering quadrature polarimetric data. Likewise, the evidence to date shows that rarely does C-band penetrate through the foliage in closed moist forests.

Airborne radar data acquisition largely has been restricted to the dry season. It has been noted that significant changes in radar backscatter were identified comparing dry and wet season imagery acquired during the Nigerian survey. 28/ These changes were mainly attributed to moisture differences. Very few multi-temporal data sets have been obtained, even within the same season. A major use of satellite radar imagery is expected to be the detection of (man-made) changes in forest cover, so that there exists an urgent need for exploring this dimension.

Spaceborne SAR investigations

Spaceborne SAR imagery of tropical terrain has been acquired during the experimental SEASAT (1978), Shuttle Image Radar (SIR-A) in 1981 and SIR-B in 1984 missions. These radars operated at the L-band and transmit and receive horizontal polarization (LHH). The spatial resolution achieved by each system varied between 25 metres, 40 metres and 18-60 metres, respectively. SIR-A and SIR-B provided only relatively narrow swath coverage of 50 km and 15-40 km, respectively. The combined total coverage in the humid and seasonally humid tropics exceeded a land area of 1.5 million km.

Multi-temporal SAR data are extremely limited and are restricted to some repeat coverage of the SEASAT SAR within the mask of the Merritt Island, Florida, receiving station, and to occasional overlap of SIR-A and SIR-B image swaths. With the exception of one study, 29/ lack of data has virtually precluded the study of spaceborne SAR imagery for change detection within tropical forest environments. The few studies that have been carried out to

assess environmental conditions and dynamic land use phenomena have had to rely on single date spaceborne SAR data.

Both computer-assisted and visual interpretation procedures have been employed in the analysis of spaceborne SAR data for tropical vegetation and land use investigations. In addition, most studies suffered from a lack of ground information and knowledge of specific environmental and target parameters at the time of data acquisition, thus limiting the reliability of interpretation results.

The imagery acquired during the SIR-A mission in November 1981 provide a useful yet little known source of information representative of all major tropical forest regions of the globe. There is evidence that SIR-A imagery (I-NH) at a scale of 1:250,000 is suitable for identifying the nature and extent of tropical forest conversion such as commercial timber harvesting operations, man-made grasslands for cattle ranching projects as well as natural grassland successions and, to a limited extent, settlement colonization and agricultural schemes. 30/

It has been demonstrated that clearings within the tropical forest of Amazonia may exhibit different radar backscattering behaviour because of age and clearing practices. 31/ 32/ This study revealed that the L-band would be helpful in determining primary forest composition. Data, however, were insufficient in area coverage to determine the exact rates of deforestation.

The potential of multi-temporal SEASAT and SIR-B data for defining areas of forest change, different forest categories and reforestation sites in Florida has been evaluated. 33/ Primary categories of forest change such as deforestation and reforestation were identified with relatively high accuracy. Reforestation stages were detected with modest success.

Using SIR-B data at two different incidence angles, 34/ it was possible to distinguish and map swamp and lowland forest, tidal forest, wetland and clear-cut areas in the coastal rain forest of Borneo. Radar backscatter values for swamp areas were noted to change as a function of incidence angle. The SIR-B data were not suited for discriminating between different forest types within the mountainous interior of Borneo.

Studies have been performed using the multi-incidence angle SIR-B data of Bangladesh to characterize forest canopy and assess radar penetration capabilities. 35/ They were able to map flood boundaries beneath mangrove vegetation canopies. Breaches and holes in the natural canopy structure were also easily detected.

Also, SIR-A data were examined 36/ as part of a multi-sensor study for forest classification in the Colombian Amazon. Although their forest typing exercise met with little success, a clear discrimination of forested and non-forested areas was noted. Boundaries between savannah vegetation, tropical forests, flood-plain vegetation and clearings were delineated without difficulty.

The radar backscatter properties of flood-plain vegetation using multi-frequency SAR data were examined. 37/ Alluvial forest areas were

Table 1: SUMMARY OF SAR APPLICATIONS RESULTS IN TROPICAL FORESTS

Applications Area	Country	Band[a]	Resolution	Reference
Road detection	Sarawak	X	6 m	Thompson and Dams 1990
	Peninsular Malaysia	X	6 m	Ahmad et al. 1988
	(Cameroon[1]	L	40 m	Werle 1989a)
	Belize	L,P,C[2]	10 m	Zebker et al. 1990
Forest inventory information	Peninsular Malaysia	X	6 m	Ahmad et al. 1988
	(Nigeria	X	> 30 m	Sicco Smit 1978)
	(Colombia	K_u,X,L	10-22,16,40 m	de Molina and Molina 1986)
Clearcut detection	Cameroon	L	40 m	Werle 1986
	Venezuela	L	40 m	Werle 1986
	Indonesia	L	40 m	Werle 1986
	Brazil(?)	L	40 m	Stone & Woodwell 1987
	Colombia	K_u,X,L	10-22,16,40 m	de Molina & Molina 1986
	Costa Rica	X	6 m	Dams et al. 1987
	Belize	L,P,C[2]	10 m	Zebker et al.
Clearcut revegetation	Cameroon	L	40 m	Werle 1989a
	Venezuela	L	40 m	Werle 1989a
	Indonesia	L	40 m	Werle 1989a
	Costa Rica	X	6 m	Dams et al. 1987
Settlements	Nigeria	X	30 m	Hunting, 1984
	Paraguay	L	40 m	Werle 1989a
	Indonesia	L	40 m	Werle 1989a
	Sarawak	X	6 m	Thompson and Dams 1990
	Colombia	X	6, 12 m	de Molina and Molina 1989
Agricultural conversion	Paraguay	L	40 m	Werle 1986
	Sarawak	X	6 m	Thompson and Dams 1990
	Peninsular Malaysia	X	6 m	Thompson and Dams 1990
	Colombia	X	6, 12 m	de Molina and Molina 1989
Tree plantations	Guatemala	K_u	10 - 22 m	Dellwig et al. 1978
	Indonesia	L	40 m	Werle 1989a
	Australia	X	12 m	Lowry et al. 1986
	Congo	X	6 m	Thompson and Dams, 1990
	Peninsular Malaysia	X	6 m	Ahmad et al. 1988
	Belize	L,P,(C)	10 m	Zebker et al. 1990

Table 1: SUMMARY OF SAR APPLICATIONS RESULTS IN TROPICAL FORESTS (Continued)

Applications Area	Country	Band#	Resolution	Reference
Mangrove forests	Indonesia	X, L	40 m	King 1985
	Panama	K_a		Lewis & MacDonald 1973
	Sarawak	X	6 m	Thompson and Dams 1990
	Australia	X	12 m	Lowry et al. 1986
	(Bangladesh	L	≈16 - 33 m	Imhoff et al. 1986)
	(Florida	L	25 m	MacDonald et al. 1981)
Flooding	Bangladesh	L	28 m	Imhoff et al. 1986
	Australia	L	40 m	Werle 1989a
	Indonesia	L	28 m	Ford & Sabins, 1985
	Guatemala	L	25 m	Pope 1987
	Colombia	X	6, 12 m	de Molina and Molina 1989
	Indonesia, Borneo	L	≈ 20 - 30 m	Ford & Casey 1988
Drainage	Nigeria	X	> 30 m	Sicco Smit 1980
	Colombia	K_a,X,L	10-22,16,40 m	de Molina & Molina 1986
	Brazil	X,L	16, 40 m	Ford & da Cunha 1985
	Cameroon	L	40 m	Werle 1989a
	Sarawak	X	6 m	Thompson and Dams 1990
Broad vegetation classes	Brazil	X	16 m	Furley, 1986
	Nicaragua	K_a	10-20 m	Trevett 1986
	Togo	K_a	> 20 m	Gelnett et al. 1978
	Nigeria	X	30 m	Hunting 1984
	Colombia	X	≈ 10 - 22 m	de Molina et al. 1973
	Colombia			Trevett 1986
	Colombia	K_a,X,L	10-22,16,40 m	de Molina & Molina 1986
	Colombia	X	6, 12 m	de Molina and Molina 1989
	Australia	X	6 m	Lowry et al. 1986
	Indonesia, Borneo	L	≈ 20 - 30 m	Ford & Casey 1988
	(Brazil	X	≈16 m	Disperati and Keech 1978)

Notes:
1. Studies in parentheses ( ) report negative findings for that application.
2. Partial success, depending on local conditions.

Wavelengths:
K_a = ~1 cm; X = 3 cm; C = 6 cm; S = 10 cm; L = 23 cm; P = 68 cm

Table 2: SELECTED PARAMETERS OF ALL CIVILIAN SAR SATELLITES

	Seasat USA	ALMAZ USSR	ERS-1 ESA	J-ERS-1 Japan	(SIR-C)[3] USA	ERS-2[1] ESA	RADARSAT Canada	EOS[2] USA
Operation	1978	90-93	91-93	92-94	93,4,5	94-96	94-99	99(?)-
Radar Bands	L	S	C	L	C,L,X	C	C	C,L (X)
Polarimetry					yes			yes
Swath width (km)	100	30-300	80	75	15-90	80	50-500	50-500
Resolution (m)	25	15-300	30	18	~30	30	10-100	10-100
Incidence angle (°)	22	40-60	23	39	15-55	23	20-59	15-55
Max. N. Latitude (°)	72	73	80	80	53	80	90	
o/b recorder		yes		yes	(yes)		yes	(yes)

[1]For purposes of this discussion, ERS-2 parameters are assumed similar to those of ERS-1.

[2]Current NASA planning has deleted the SAR as a facility instrument on EOS, and is seeking approval for a separate but related SAR satellite. System parameters of the proposed SAR are not established, but are likely to be rather close to those listed above.

[3]Shuttle radar flights (SIR) each last about one week, as did SIR-A (1981) and SIR-B (1984).

clearly identified on SIR-A I-band data, but could not be separated from surrounding forest areas on X-band airborne SAR data.

Seasonal flooding of lowland terrain was monitored in tropical forests of Guatemala using multi-temporal SEASAT SAR as well as airborne SAR data. 38/ Radar backscatter values of vegetated flooded terrain was found to be at a maximum under small incidence angle illumination.

These findings and others are summarized in Table 1, which shows that many different kinds of information useful for tropical forest management can be obtained from suitable radar data. With one exception, studies at the C-band are noticeably absent from the tabulated results.

Forthcoming Radar Satellites

The decade of the 1990s offers several satellite radar systems of interest for tropical forest monitoring. Civilian radar (SAR) satellites are summarized in Table 2. Several patterns emerge from the parameters tabulated.

Although the satellites span frequencies from C-band to L-band, the predominant frequency available will be C-band. When only the operational systems are considered, C-band is clearly the frequency of central interest. The is significant, in that C-band is the frequency for which there is the least amount of prior data available, and for which the most preparation is warranted.

Swath widths and resolutions are similar, except that RADARSAT offers a choice of coverage, ranging from 10 m resolution at 50 km swath width to 100 m resolution at 500 km swath width, using nominal specifications. Should incidence angle prove to be a parameter of value in scatterer discrimination, incidence angle selection is available on three of the operational systems. Additional information on RADARSAT may be found. 39/ 40/ 41/

Quadrature polarization data will not be available until the middle of the decade, and only for experimental purposes from SAI-C/X-SAR. If the Earth Observation Satellite (EOS) SAR is approved, operational quadrature polarimetry data will become available only after the end of the decade. A major advantage of satellite SAR systems is their ability to provide repeat coverage for change detection analysis. It is expected that even at C-band, change in forest cover due to natural or human causes will be evident through multi-temporal analysis. All weather operation and the ability to co-register the data sets are essential elements of this method; both elements are supported by the operation systems listed in the table.

The Soviet Union has announced its intention to make imagery available from its Almaz radar satellite, due to be launched in November, 1990. The S-band frequency and variable imaging parameters suggest that data from this system are of potential interest in the tropical context.

Two interesting initiatives are not shown in the table, due to the fact that they are in only conceptual stages. The National Aeronautics Space Administration (NASA) proposed in 1988 that the Space Station should carry a

Table 3: BASIC CHARACTERISTICS OF TYPICAL OPTICAL AND MICROWAVE SENSORS

Sensor	Mode	Swath(km)	Resolution	Incidence
L-MSS	Standard	185	≈ 80 m	-11° to 11°
L-TM	Standard	185	30 m	-11° to 11°
SPOT/HRV	Multispectral	60	20 m	-31° to 31°
SPOT/HRV	Panchromatic	60	10 m	-31° to 31°
AVHRR	Standard	≈2000	≈1100 m	-45° to 45°
ERS-1	SAR	80	30 x 30 m (4 looks)	~ 23°
RS-SAR#	Standard	100	28 x 30 m (4 looks)	20° to 49°
RS-SAR	High Resolution	55	8 x 8 m (1 look)	20° to 49°
RS-SAR	Extended	100	28 x 30 m (4 looks)	49° to 60° and 10° to 20°
RS-SAR	ScanSAR	500	100 x 100 m (8 looks)	20° to 49°

RS = RADARSAT

Table 4: SUMMARY OF INFORMATION REQUIREMENTS AND APPROPRIATE SENSORS

PART I: Broad Scale

Global, continental, national	**Agencies concerned:**
Typical mapping scales: $1:10^6$ to $1:10^7$ Spatial resolution: 0.1 to 10 km	International organizations International development agencies Global environmental research groups
Information requirement	**Appropriate sensor(s)**
Broad vegetation classes	NOAA/AVHRR RADARSAT ScanSAR
Vegetation cover/vigour	NOAA/AVHRR
Length of growing season	NOAA/AVHRR
Large area vegetation change	RADARSAT ScanSAR NOAA/AVHRR

PART II: Medium Scale

National, regional	**Agencies concerned:**
Typical mapping scales: $1:10^4$ to $1:10^6$ Spatial resolution: 10 to 1000 m	National, state, and provincial Natural Resource, Environment, and Parks Departments

Table 4: SUMMARY OF INFORMATION REQUIREMENTS AND APPROPRIATE SENSORS (continued)

Information requirement	Appropriate sensor(s)
Topography	Air photo, SPOT/HRV (Radar)[2]
Vegetation inventories	Air photo, Landsat/TM, RADARSAT/Standard ERS-1, J-ERS-1
Mangrove forests	Landsat/TM, SPOT/HRV, RADARSAT/Standard ERS-1, J-ERS-1
Drainage networks, standing water	Landsat/TM, SPOT/HRV RADARSAT/Standard ERS-1, J-ERS-1
Standing water under canopy	(RADARSAT/Standard) (ERS-1) J-ERS-1
Roads and settlements	SPOT/HRV RADARSAT/High Resolution
Change detection	SPOT/HRV, Landsat TM RADARSAT Standard ERS-1, J-ERS-1
Forest damage	Air photo, Landsat/TM (based on temperate latitude studies)
Revegetation assessment	Landsat TM, SPOT/HRV (radar)
Plantation mapping	(RADARSAT/High Resolution) SPOT/HRV, Landsat TM
Agricultural conversion (vegetation change)	(RADARSAT/Standard) RADARSAT/High Resolution SPOT/HRV, Landsat TM (ERS-1)
Fire detection	NOAA/AVHRR

Table 4: SUMMARY OF INFORMATION REQUIREMENTS AND APPROPRIATE SENSORS (continued)

PART III: Small Scale

Local	**Agencies concerned:**
Spatial resolution 1 to 10 m Typical mapping scales: $1:10^3$ to $1:10^4$	Resource companies, Municipalities, National and local parks administrations, engineering companies, non-governmental organizations
Information requirement	**Appropriate sensor(s)**
Vegetation species mix	Air photos, (airborne SAR)
Wildlife habitat	Air photos, Landsat TM, SPOT/HRV (airborne SAR)
Tree diameters and heights	Air photos, (airborne SAR)
Roads, trafficability	Air photos, SPOT/HRV, airborne SAR RADARSAT High Resolution
Plantation mapping and assessment	Air photos, airborne SAR, SPOT/HRV Landsat TM (RADARSAT High Resolution)

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1. In this table we have indicated Landsat/TM and SPOT/HRV where studies have shown that Landsat/MSS is effective, because our experience with forestry applications at temperate latitudes has indicated that customers are usually willing to pay the extra cost for the additional information content of these sensors. We have not indicated aerial photography ("Air photo") for applications which can be done with satellite data because customers generally prefer the much lower cost per unit area of satellite data.

Radar sensor applicability for spacecraft is estimated based on the limited data available, and for aircraft is based on the extensive experience of Intera (Dams *et al.* 1987) using high resolution X-band SAR in various tropical applications.

2. Parentheses ( ) indicate conditional applicability of the enclosed sensor.

P-band SAR whose main justification would be tropical forests. The proposal was not accepted at that time, although P-band forestry studies are continuing. These studies show considerable promise, and could influence wavelength selection of the EOS SAR during its final design and approval process.

A second initiative is developing through the International Space University. The International Space University has proposed to begin the process of design, construction, launch, and operation of a "light-sat" SAR at P-band, conceived with tropical forest monitoring as the primary objective. Satellite data would be down-linked through existing low-rate meteorological telemetry channels, and would be processed at centres distributed throughout the world. If approved - and it is a long way from maturity at this time - it could lead to a relatively low-cost source of P-band satellite SAR data of medium resolution well before the end of the decade.

The Role of Radar Satellite Missions

In approaching the issue of satellite SAR, airborne SAR, and optical data for tropical forest management, it is very helpful to recognize a relationship between the area for which information is required and the level of detail desired. There are also corresponding relationships between the area covered by a sensor and its spatial resolution (see Table 3), and between the spatial resolution of sensors and the level of detail available from them. 42/ These relationships result in natural groupings between the information requirements of various agencies and the appropriate sensors to satisfy the information requirements. We have emphasized three such groupings in Table 4, where we match information requirements with the sensors which appear, at present, appropriate to satisfy the information requirements.

An important dimension not covered in either Table 3 or Table 4 is that of time. Spacecraft radars may be relied upon to provide repeat coverage of any given site, even if cloud covered. The time between coverage opportunities is a function of satellite orbit, swath width, and, indirectly, resolution. Revisit intervals for the systems listed in Table 3 range from 3 days to about 35 days, based on current knowledge of system parameters. Perhaps of more importance, the issue of establishing a requirement on "temporal resolution" (an entry that would be more suitable for Table 4) requires specific investigation, particularly in the light of system capabilities now projected. Temporal resolution would be dependent on season and anticipated levels of human activity in specific tropical forest regions. Whereas this dimension is not considered explicitly in the discussion that follows, it remains an important aspect of the forest monitoring issue. The change detection potential of composite pairs of images gathered at two different points in time should add considerably to the value of spaceborne radar data in tropical forest monitoring.

Numerous studies have shown microwave backscatter to provide information about vegetation which is complementary to the information provided by optical sensors. 43/ 44/ 45/ 46/ It is reasonable to expect, therefore, that microwave satellite data will also prove useful as a complement to optical data for mapping broad vegetation classes over wide areas. These considerations are based on the assumption that there are sufficient data

available to perform both single pass and multi-temporal monitoring. Due to the fact that large amounts of data are required, this is not a trivial condition, and cannot be taken for granted. If tropical nations were to be obliged to pay commercial rates for all of the data that they require, it is likely that they would acquire rather less data than are needed for full monitoring functions. The issue of data policy, its pricing and terms of availability, becomes of central importance in the context of tropical forest monitoring. It would be constructive if this issue were to receive attention from the nations sponsoring these remote sensing spacecraft. There is an evident justification for such data to be made available through methods that are more enlightened than is the current commercial approach.

CONCLUSIONS

Radar data from satellites will be routinely available during the 1990s, and presumably for many years thereafter. One of the most significant applications for such data is tropical forest monitoring, as has been documented in numerous field reports. However, there is at present virtually no quantitative knowledge base upon which to build an operational capability to use such data, particularly on C-band, which is expected to be the most continuously maintained frequency throughout the decade. There is an urgent need to augment C-band experience over tropical forests, using both airborne systems dedicated deployments, and with studies based on ERS-1 data, the first radar satellite to be operational. In parallel with the technical developments required, there need to be studies towards enhancing the infrastructure in tropical countries so that they are better prepared to use such data for active environmental management, and reconsideration of the remotely sensed data pricing policy so that sufficient data may be reliably acquired where they are needed at reasonable cost.

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REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEM TRAINING REQUIREMENTS IN ARCTIC CANADA*

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ABSTRACT

As Canada's northern citizens assume greater responsibility for the development and management of their natural resources, direct and full access to the benefits of remote sensing and the new mapping technologies will become increasingly important. Establishing self-sustaining infrastructures will require a concerted effort at all levels. The physical infrastructure can now be established rapidly and at a cost which has declined significantly in recent years. Establishing and sustaining the necessary human infrastructures is now recognized widely as the most challenging task. The approach to this task must be based on a fully integrated training programme. This paper will consider the unique training challenges which will have to be met in the north. The authors will discuss a training strategy for remote sensing and geographic information systems (GIS) in northern Canada. This strategy attempts to make maximum use of existing training resources and recognizes the practical need to develop operational skills rapidly enough to fuel the broader effort to supply timely and reliable resource information over the vast territory of Canada's north. The strategy stresses the special needs of native peoples to participate fully in the development process. In achieving this, the authors draw on the experience of the Canada Centre for Remote Sensing (CCRS) Technology Transfer Programme and Arctic College.

INTRODUCTION

As Canada's northern citizens assume greater responsibility for the development and management of their natural resources, direct and full access to the benefits of remote sensing and the new mapping technologies will become increasingly important. Establishing self-sustaining infrastructures will require a concerted effort at all levels. The physical infrastructure can now be established rapidly and at a cost which has declined significantly in recent years. Establishing and sustaining the necessary human infrastructures is now recognized widely as the most challenging task. The approach to this

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task must be based on a fully integrated training programme. Over the years, a large number of academic institutions, government departments and public interest groups have attempted to develop learning opportunities in environmental studies for northern Canadians. The programmes have exhibited varying degrees of success and, for the most part, have resulted from the good intentions of individual organizations or have been designed to help fulfil a condition imposed on a development project or to help deal with affirmative action. These courses and training programmes have had some of the following elements in common:

(a) Courses were usually of a short duration, and were offered, for the most part, during the summer period.

(b) The selection of students was not rigorous, as the goal was to involve as many northerners as possible in the programme. In other words, success was measured in numbers of participants, and not in the quality of the graduates.

(c) In many cases, the lack of formal student evaluation procedures made it difficult for graduates to "transport" their training to other institutional or employment settings. Without well-documented and accepted evaluation procedures, any certificates given to participants have been of questionable value and utility.

(d) Many courses have not led to long-term employment,or to the prospect of further education. Training opportunities have related specifically to the situation at hand and have not taken into account the academic requirements of the student. The result is that once the employment or the programme was finished, the skills learned by the participant were difficult to transport elsewhere.

(e) The demand for the training did not come from within the community, but rather from outside. This situation did not foster much in the way of community support for programmes or their participants.

(f) The delivering agencies and their consultants assumed that educational programmes designed for southern consumption had to be watered down, and standards lowered, for northern consumption. 1/ 2/

The result of this haphazard approach to the development and delivery of environmental training opportunities was to create a group of semi-trained, semi-educated individuals interested in obtaining employment in environmentally-related areas. While many moved from community to community in the north, the skills and knowledge held could not be taken and applied outside of the Northwest Territories (NWT). An integrated approach to training became an absolute necessity.

APPROACH TO GEOGRAPHIC INFORMATION SYSTEMS TRAINING

Two recent initiatives provide the best example of how modern technology and methodology are being successfully integrated into the northern training environment: the Canada Centre for Remote Sensing (CCRS) Technology Transfer

Programme and the Geographic Information System (GIS) stream of the Environmental Technology Programme.

The Canada Centre for Remote Sensing is a branch of the federal Department of Energy Mines and Resources. The Technology Transfer Section (TTS) with the Centre's Application's Division is responsible for a broad spectrum of remote sensing technology transfer efforts. Two of the best known of these efforts are the Section's Technology Transfer Program (TTP) and the Training Unit (TU). The TTP mandate is to assist in the adaptation, evaluation and transfer of remote sensing technology from the federal level to the provinces and territories. The TTS has completed several successful programmes to date in the Maritimes, Manitoba, Newfoundland and Saskatchewan. It has also developed special radar-oriented programmes with several provinces. The TTP carries out its work under the terms of a Memorandum of Understanding drawn up between the two participating agencies. Part of the Programme's success lies in its flexibility, although all cases have in common a set of co-operative test projects. CCRS normally contributes a specialist and loans image analysis equipment for the duration of the programme, which is normally two years.

Technology transfer is a complex process and necessarily involves much more than simple technology promotion and trial. The TTP field officer works actively on all elements of technology transfer, including training. Each programme incorporates a wide range of training opportunities and the field officer is supported in this effort by the TTS Training Unit.

The TU develops training curricula and training aids based on the principles of adult learning and presents the resulting workshops directly to the user or in cooperation with the field officers. The resources are made available as widely as possible, not only to TTP personnel, but also to anyone involved in training in remote sensing and related technologies. The TU is also actively involved in the design and modification of training aids for customized workshops to meet the training needs of companies, institutions and international organizations such as the Geomatics Industry Association of Canada and the Food and Agriculture Organization of the United Nations (FAO).

A Technology Training Programme is currently nearing its completion in the Northwest Territories. This programme has had as its main objectives increasing the awareness of the proven potentials of remote sensing and related technologies such as GIS, and the development of self-sustaining capabilities for the application of this technology. In co-operation with the Department of Renewable Resources of the Government of the Northwest Territories, a portfolio of pilot projects has been undertaken and numerous training opportunities provided.

Training is one of the most critical prerequisites for the success of the Technology Transfer Programme. To this end, in addition to conducting workshops for professionals, the TTP has been co-operating with Arctic College to evaluate the existing training needs and the resources available to deliver courses. The overall result of this initiative has been to understand the unique training refinements of NWT games and to begin developing appropriate curricula and training aids.

Arctic College

In 1982, a five-member special committee of the Legislative Assembly released a report entitled Learning: Tradition and Change in the Northwest Territories. This report became the blueprint for the re-design of the territorial education system, from kindergarten to university. Of the 49 recommendations contained in the report, one recommendation was for the establishment of a decentralized college, to be called Arctic College. In August 1984, the Executive Council of the Northwest Territories gave approval to the mandate of the new Arctic College for the co-ordination and delivery of all post-secondary adult education and training, and established a strategic plan for its development.

Environmental Technology Programme

One of the two environmental and renewable resource training programmes offered by Arctic College is the Environmental Technology Programme. This Programme is the first in the eastern Arctic that is based on a demonstrated need for post-secondary environmental training, and which marries the rigour of southern academic learning with northern needs, interests, and cultural knowledge. The programme was established in 1986 at the Nunatta Campus of Arctic College, located in Iqaluit on Baffin Island, and complemented the existing Renewable Resources Technology Programme offered in Fort Smith. As with other Arctic College programmes, a detailed needs assessment was completed to ensure that the programme could realistically meet the expectations of potential employers, the needs of the community, and in particular, the needs of the student, while maintaining a high-quality learning experience.

The resulting programme is a three-year co-operative style programme that links on-the-job work experience with academics and skills training, leading to a diploma in Environmental Technology. Graduates of the programme possess the necessary skills and knowledge qualifying them for employment opportunities with the territorial and federal governments, private industry, and other agencies. Examples of environmentally-related positions include: Renewable Resource Officers, Water Resource Officers, Land Use Planning Technicians, Community Planning Technicians, Environmental Protection Officers, Parks Wardens, etc.

Nature of the Students

In addition to successfully identifying the knowledge-gap and the resources needed to undertake training programmes, it is critical that any programme take into account the nature of the student or participant. Without a realistic idea of the background and experience of the participants in a training exercise, including potential cultural and social factors, it is likely that the best designed training programme will fail. In general, students entering the Environmental Technology Programme have the following characteristics:

- are 25 to 30 years old (average age of 29);
- are Inuit;

- are male, married, with children;

- are bilingual (English and Inuktitut), but require assistance in developing English written and oral skills, as English is the second language for most students;

- currently employed, in an environmentally-related position, or otherwise employed, but wishing to change careers to enter environmentally-related work;

- have attended some high school, but more likely than not, are operating at a grade 10-12 level; and,

- have expressed a desire to remain within the eastern Arctic, close to home and family, unwilling to relocate to obtain further training or employment.

It must be pointed out that this profile is expected to change as the programme matures and as younger students become available from high schools. Without "role models" currently employed in high-profile environmental work, younger students show little interest in following careers in environmental or science fields.

Also, while the students are predominantly male, the number of female students is projected to increase as younger Inuit women become more actively involved in land-oriented employment. This has traditionally not been the case, as Inuit have followed employment patterns which correspond to traditional male-female roles.

GIS within Arctic College

In November of 1989, a workshop was held in Iqaluit, NWT to discuss the future applications of remotely sensed information and Geographic Information Systems in environmentally-related employment in the North. Participants from across the Northwest Territories met, and indicated that a knowledge of GIS will become essential in most environmental jobs in the next few years. This conclusion was further reinforced by an assessment of similar environmental training programmes in Canada, conducted by Environmental Technology Programme staff.

In addition to the obvious need to introduce GIS and remote sensing directly into the main Environmental Technology diploma programme, it also became clear that short training courses in GIS will be required for field workers in land use planning, for those involved in administering land use plans and in environmental assessment, and for professionals currently involved in various environmentally-related employment that will soon require a working knowledge of GIS applications.

The Environmental Technology Programme introduced GIS and remote sensing courses into its curriculum in the fall of 1990. In keeping with the recommendations of practitioners who attended the November workshop, these courses will stress the "basics" in GIS and remote sensing. This includes areas such as an introduction to GIS and its and a knowledge of various

applications, a familiarity with remotely sensed data, a knowledge of computer mapping, a basic familiarity with computers and a knowledge of various data management programmes. Participants also stressed that students should not become "apostles" of any one particular system, but should feel comfortable with many basic aspects of GIS programmes (the Environmental Technology Programme uses IDRISI, EPPL7 and OSU as its GIS training programmes).

Secondly, in co-operation with the Canada/NWT Centre for Remote Sensing, GIS and remote sensing training will be offered at a higher level on specific systems or topic areas. These courses will be designed for graduates of the Environmental Technology Programme and for other professionals in environmentally-related employment. Short courses of this nature will ensure that specific needs of user agencies are addressed while providing flexibility to take advantage of rapidly changing technology. Also included in this category of training will be "training for the trainer" workshops to allow for the better integration of the technology back into the workplace.

Thirdly, the November workshop also highlighted that, in addition to the specific training needs of Environmental Technology graduates and other professionals, there is also a clear need to provide access to training for those who must collect data for use in the various computerized planning systems and for those who must make decisions based on this information. With this in mind, the Environmental Technology Programme plans to develop a series of workshops which will familiarize field workers and board members alike with GIS and allow them to better use the evolving technology. These workshops will be run in conjunction with specific user groups and government agencies, taking advantage of the wide-ranging knowledge base that already exists in the NWT.

The strength of these programme options has also been increased through an arrangement with the Geographic Information Systems Programme of the School of Natural Resources of Sir Sandford Fleming College. This link will provided residents of the NWT with access to training opportunities which are designed specifically for northern needs, and will deal with the most up-to-date technology.

TRAINING CANNOT DO IT ALL

Although this paper has described the ways in which training in remote sensing and GIS is being developed to meet the needs of the northern community, it is also clear that the success of any programme cannot rest solely on training. Training will fail if the audience assessment has been inaccurate, participants' motivation is low, there is no management support for innovation or for training, there is no infrastructure for application in place, and sustained access to training is not planned. Training will succeed when the needs meet the mandate and perception of the receiver, the knowledge gap is clearly defined, the need for management support of training is recognized and there is an immediate application of the skills learned.

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REMOTE SENSING FOR AGRICULTURAL DEVELOPMENT*

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INTRODUCTION

The Food and Agriculture Organization of the United Nations (FAO) has remote sensing activities that are wide-ranging and that involve most of technical services in the departments of agriculture, forestry, fisheries, economic and social policy and development. All remote sensing activities of FAO are co-ordinated by its Remote Sensing Centre, which belongs to the Research and Technology Development Division of the Agriculture Department. The major FAO users of remote sensing are represented in the Inter-Departmental Remote Sensing and Meteorological Data Users Committee. The main objective of this Committee is to strengthen the linkages between the Remote Sensing Centre and users of its services, increase their influence on the type of services provided and facilitate the exchange of information on relevant remote sensing applications.

The Centre was established in 1980, in recognition of the growing importance of remote sensing for the provision of information on land and water resources and for environmental monitoring. Recommendations of the Committee on the Peaceful Uses of Outer Space (COPUOS) and its Scientific and Technical Sub-Committee that FAO should establish a remote sensing centre for renewable natural resources played an important role in this decision. The Centre has an inter-departmental function, providing a wide range of remote sensing and agrometeorological services. In accordance with the FAO mandate, the main applications are in agriculture, forestry, rangelands and fisheries. The organizational structure of the Centre is illustrated in figure 1.

The main objectives of the FAO Remote Sensing Centre are to strengthen the self-reliance of developing countries in the application of remote sensing to mapping, assessment and management of their renewable natural resources and thus to contribute to their sustainable development. Particular emphasis is on remote sensing applications related to food production and food security in the least developed countries. Environmental monitoring by satellites is

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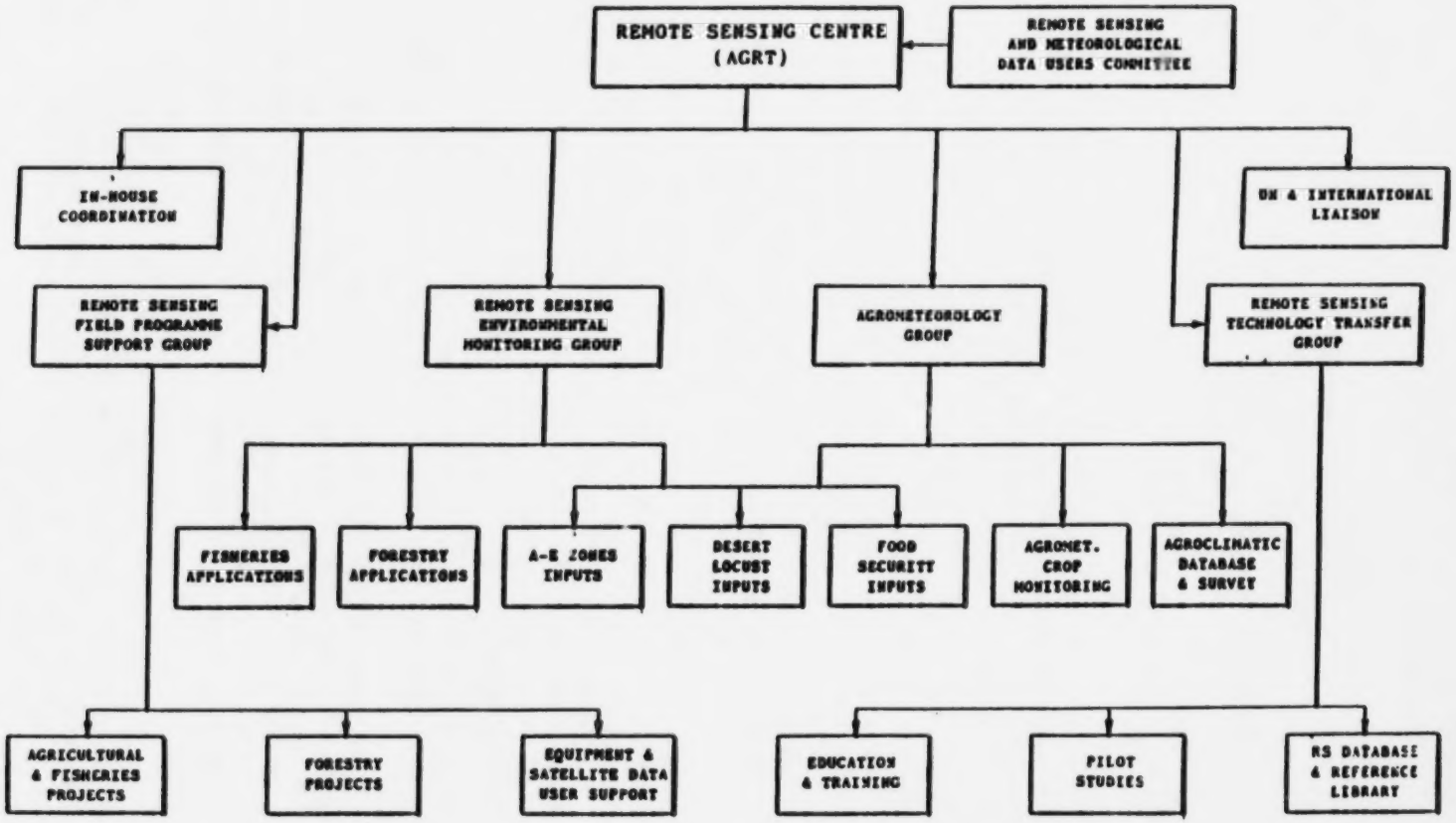

Figure 1. Organizational Diagram Of The Food And Agricultrual Organization of the United Nations (FAO) Remote Sensing Centre. For 1990 to 1991.

another high priority task of growing importance in the Centre's activities. In the framework of its technology transfer activities, the Centre is strengthening its function as a clearing house for information on applications of remote sensing to development, management and protection of renewable natural resources.

Highlights of FAO's remote sensing activities

Highlights of the past year's activities were the continuation and further development of operational, near real-time monitoring of vegetation and precipitation in Africa by the FAO Africa Real Time Environmental Monitoring Using Imaging Satellites (ARTEMIS) system for receiving and processing environmental satellite data; co-operation with ESA on development of the satellite communication system Data and Information Available in Africa (DIANA) for real-time transmission of ARTEMIS products to users in Africa; co-operation with the FAO Forestry Department on the use of remote sensing data for tropical forest cover assessment and monitoring of deforestation; provision of technical backstopping to over 50 FAO, United Nations Development Programme (UNDP) and trust fund field projects with remote sensing activities; development of techniques for operational applications of satellite high resolution optical and microwave imagery in relevant agricultural, forestry and fisheries projects; continuation of remote sensing training activities in cooperation with the United Nations Outer Space Affairs Division, World Meteorological Organization, (WMO), European Space Agency (ESA), Italy, Germany, Australia, Spain, Bhutan, Costa Rica, Thailand and Tunisia; provision of information and advisory services on applications of remote sensing in agriculture, forestry and fisheries and, last but not least, formulation of FAO participation in the International Space Year (ISY).

The overall framework for planning of FAO's remote sensing activities is provided by the recommendations of the UNISPACE 82 Conference, COPUOS, priorities of the Group of 77 and by the annual ACC Inter-Agency Meetings on outer space activities. During the last year, the Remote Sensing Centre's work was focused on the following areas:

- Monitoring of vegetation and precipitation in Africa;
- Remote sensing technology transfer through training, pilot studies and advisory services;
- Development and backstopping of field projects or project components;
- Coordinating and assisting remote sensing activities conducted by other FAO units.

Starting from January 1990, another major activity area of the Centre is agrometeorology and agroclimatology. Below is a summary of the main activities under the above headings during the last year.

Monitoring of vegetation and precipitation in Africa

Since August 1988, the FAO Remote Sensing Centre has been operationally monitoring precipitation and vegetation in Africa based on semi-automatic processing of image data recorded - by the environmental satellites METEOSAT and National Oceanic Atmospheric Administration (NOAA). Development of this dedicated system for ARTEMIS was the result of close co-operation between the FAO and the National Aerospace Laboratory (NIL) of the Netherlands as the prime contractor, the Earth Resources Branch of the NASA Goddard Space Flight Centre that used NOAA-Advanced Very High Resolution Radiometer (AVHRR) data processing into vegetation index products, the Universities of Reading and Bristol, and the United Kingdom that used Meteosat data processing into precipitation assessment products and various other research groups.

The main user of ARTEMIS precipitation and vegetation index estimates are the FAO Global Information and Early Warning System of Food and Agriculture and the FAO Emergency Centre for Locust Operations (ECLO).

During 1990 two major ARTEMIS-related developments were initiated:

(a) Development, in close cooperation with the main user GIEWS, of new techniques for improved early identification of areas threatened by agricultural drought based on integration of satellite-based ARTEMIS products with field agrometeorological data; this had been preceded by a study of information requirements of Global Information and Early Warning System (GIEWS). These new techniques will be user, rather than technology, driven. The Advanced Resource Technology Program of the College of Agriculture, University of Arizona, United States has been contracted to assist with development of the new integrated techniques;

(b) Co-operating with the European Space Agency on development of a dedicated satellite telecommunication system, DIANA, for real-time transmission of ARTEMIS products to their users in Africa.

The following ARTEMIS products are supplied to GIEWS for food security and ECLO at 10-day and monthly intervals:

A. Ten-day basis

1. DCCD (Dekad Cold Cloud Duration)

2. DNRFD (Dekad Number of Rainfall Days)

3. DERF (Dekad Estimated Rainfall) only for the months June to October

4. DNDVI (Dekad Normalized Difference Vegetation Index) for the continents of Africa and Asia (resolution 7.6km)

5. NOAA-AVHRR Low Area Coverage (LAC) data (resolution 1 km x 1 km) for selected areas in Mali, Niger and Mauritania for monitoring vegetation in potential locust breeding areas.

B. Monthly basis

1. MNRFD (Monthly Number of Rainfall Days)

2. MERF (Monthly Estimated Rainfall) only for the months June to October

3. MNDVI (Monthly Normalized Difference Vegetation Index) for the continents of Africa and Asia

4. Vegetation Index Difference Image

   a. Between the present year and the previous year

   b. Between the present year and the median of the years 1985-1987.

C. On request

1. Composite Cold Cloud Image for rainy seasons (cumulated DCCD maps)

2. Difference Composite Cold Cloud Image

On 1 January 1990, the Agrometeorological Group joined the Remote Sensing Centre to facilitate and speed up development of improved technologies for early identification of areas threatened with crop failures, based on integration of remote sensing and agromenteorological data.

TECHNOLOGY TRANSFER

Remote sensing technology transfer activities of FAO aim at strengthening national capacities in the operational application of remote sensing in the agriculture, forestry and fisheries sectors in developing countries. FAO, in co-operation with other United Nations bodies, Member States and international organizations organizes up to ten practically oriented remote sensing training courses annually. However, during the last year only seven courses could be organized because of lack of funds. The main support for the FAO remote sensing training courses has been provided by Italy. Australia, Germany, France, the Netherlands and Spain have also co-operated with FAO in remote sensing training. Furthermore, some of these courses are organized jointly with the United Nations Outer Space Affairs Division, Economic and Social Commission for Asia and the Pacific (ESCAP) Regional Remote Sensing Programme (RRSP), United Nations Environment Programme (UNEP), United Nations Educational, Scientific and Cultural Organization (UNESCO), United Nations Disaster Relief Organization (UNDRO), WMO and with ESA. National courses are always organized in cooperation with the host country.

Remote sensing pilot studies are used to test the suitability of satellite image data and interpretation techniques in specific applications required for implementation of FAO field projects. France funded nine FAO pilot studies on the application of satellite high resolution image data in agricultural, forestry and fisheries projects, as follows:

- Soil mapping at 1:250,000 and 1:50,000 scale (Botswana)
- Soil erosion susceptibility assessment and assistance to land conservation planning (Brazil)
- Agriculture statistics (Ethiopia)
- Irrigation management and monitoring (Indonesia)
- Coastal studies (Philippines)
- Forestry mapping and monitoring (global review)
- Irrigation potential and land development (Chad)
- Tse tse habitat mapping (Tanzania).

The European Space Agency funded a pilot study for developing an operational methodology for application of satellite Synthetic Aperture Radar (SAR) data in land use and vegetation cover mapping. The field tests were conducted in Tunisia. Advisory services provided by the Centre include information on the availability and suitability of remote sensing data, equipment, techniques, education and training; assistance with formulation of training activities, selection of experts and consulting companies; recommendations on institutional inf rastructures and functional linkages between remote sensing units and users of their services.

An important role of the FAO Remote Sensing Centre is to function as a clearing house for remote sensing information relevant to agriculture, food security, forestry and fisheries, with special emphasis on developing countries. This function is being implemented through operating the World Index of Space Imagery (WISI), the World Aerial Photographics Index (WAPI)(at present completed only for Africa) and developing a remote sensing reference library focused on applications to renewable natural resources.

REMOTE SENSING SUPPORT TO FIELD PROJECTS

During the last year the FAO Remote Sensing Centre provided various technical backstopping services and assistance in project formulation to over 50 projects in 40 countries. Examples of global and regional projects with remote sensing components include the "1990 Forest Resource Assessment" which is implemented in the framework of the Tropical Forest Action Plan; the ESCAP/UNDP remote sensing project for Asia and the Pacific; development of remote sensing inputs for the food security early warning systems in Eastern and Southern Africa; reformulation of a project proposal for production of a land use map of Africa at 1:1 million scale based on satellite imagery.

Examples of national remote sensing projects backstopped by the Centre include:

A. Africa

Benin: Land cover/ecological map at 1:200,000 scale.

Ivory Coast: Strengthening of remote sensing activities for agricultural development.

Pipeline project: Preparatory assistance in developing remote sensing and GIS capacity for small scale thematic mapping.

Liberia: Land use and vegetation mapping at 1:250,000 scale.

B. Middle East

Egypt: Assisting with the establishment of a remote sensing unit at the Agricultural Research Centre.

Lebanon: Remote sensing technical assistance in planning for rural development. Remote sensing component: 1:50,000 land use/land cover map from Landsat, Satellite Probatoire pour l'Observation de la Terre (SPOT) and SOYUZ imagery.

Libya: Assisting with the formulation of a project for agricultural land use planning.

C. Asia

Bangladesh: Ten pilot studies for application of remote sensing technology in agriculture, forestry and fisheries sectors.

Afghanistan: Pipeline project for development of reliable geographic database for agricultural and other natural resources.

Philippines: Contribution to the formulation of a project for a comprehensive agrarian reform programme.

D. Latin America

Belize: Mapping of agricultural land use and forestry resources by remote sensing.

Ecuador: Operational monitoring of land use in the Amazon region.

Brazil: Strengthening the remote sensing and Geographic Information System (GIS) Centre in the San Francisco Valley Water Development Authority.

An example of a national remote sensing project backstopped by the Centre in Europe is the project on assessment of grassland productivity in Poland.

FAO MAIN USERS OF REMOTE SENSING

The main FAO users of remote sensing and examples of their major activities are as follows:

(a) Global Information and Early Warning Service (ESCG)

ESCG uses the Meteosat-based estimates of rainfall and the NOAA-AVHRR based assessments of vegetation cover as one of the inputs for operational monitoring of crop conditions by the Global Information System. The usefulness of remote sensing data is expected to increase when they are integrated with agrometeorological data.

(b) Locust Group of the Plant Protection Service (AGPP)

The Locust Group is using the rainfall and vegetation cover estimates from remote sensing data as a supplementary input for early identification of high risk localities, to be checked by aerial or ground surveys, in the Desert Locust recession area.

(c) Office for Special Relief Operations (OSRO)

OSRO uses the ARTEMIS products for verification of reports of unfavourable conditions in areas considered for special emergency or rehabilitation activities. They are also useful when reviewing requests for assistance. Special ARTEMIS products, generated in response to emergency situations such as large floods, are of particular interest to OSRO.

(d) Soil Resources, Management and Conservation Service (AGLS)

AGLS uses satellite images and/or aerial photographs in many soil survey, soil conservation, land use survey and land potential assessment projects. The Remote Sensing Centre cooperated with AGLS in formulation of a remote sensing component for the UNEP project for monitoring soil erosion in the Mediterranean coastal zone. Another joint activity concerned exploration of the possibility for improving agroclimatic boundaries in agro-ecological zones studies. AGLS started to use NOAA data to redraw the isopleths for lengths of growing periods in West Africa.

(e) Water Resources, Development and Management Service (AGLW)

AGLW uses satellite images and aerial photographs in projects for inventories and conservation of water resources, assessment of irrigation potential and exploration of ground water. In 1989, the Remote Sensing Centre cooperated with AGLW in formulation of a remote sensing component for the Nile River Basin monitoring and modelling project.

(f) Forestry Department (FO)

FO has traditionally been one of the main users of remote sensing in its field projects and regular programme activities. The range of remote sensing applications includes forest inventories, forest cover mapping, fuelwood assessment, monitoring of deforestation and forest fires. The project "Forest Resources Assessment 1990" has a significant remote sensing component. This project is implemented within the framework of the Tropical Forest Action Plan (TFAP). A major national forest inventory and monitoring project with a large remote sensing component is being implemented in Indonesia. Training courses on forestry applications of remote sensing and GIS were organized in Bhutan and Thailand in 1989.

(g) Fisheries Department (FD)

Satellite remote sensing is increasingly used in marine and inland fisheries projects for applications such as mapping and monitoring of coastal zones, assessment of the productivity of lakes and potential for aquaculture, revision of marine charts, monitoring of sea surface temperature and location of upwelling regions. The Lake Tanganyika fishery resources project and a project on aquaculture and fisheries potential in Ghana have remote sensing components. A manual, "Application of remote sensing to tuna fisheries" was published in 1989. The manual "The application of remote sensing technology to marine fisheries: an introductory manual" was translated into French and is being translated into Spanish.

(h) Statistical Development Service (ESSS)

ESSS has been increasingly using high resolution satellite data in the agricultural statistics projects. Examples of agricultural statistics projects with significant remote sensing components are in Argentina and Mauritania. ESSS and the Remote Sensing Centre co-operate in training courses on the application of remote sensing to agricultural statistics.

SPIN-OFF BENEFITS

Spin-off benefits have always played an important and often decisive role in setting up FAO priorities for new remote sensing initiatives. Examples of such spin-off benefits include development of new, or improvement of the existing techniques in the following areas:

(a) cartography, especially thematic mapping of natural resources;

(b) agricultural crop statistics, forest inventories and rangeland assessment;

(c) forecasting of agricultural crop production,

(d) early identification of areas with high risk from migratory pests, such as desert locusts, as well as areas which may suffer from agricultural drought, land degradation and other natural disasters;

(e) assessment of land potential for agricultural production, in particular in the context of comprehensive agro-ecological zoning; assessment of suitable sites for aquaculture, irrigation potential, assessment of soil erosion risk, etc.

Furthermore, important spin-off benefits are in expanding the understanding of complex environmental interactions over large areas and of integral links between the development of natural resources and environmental protection. Remote sensing is often used for monitoring of the environmental impact of large development projects. It is expected that the spin-off benefits of remote sensing technology will be significantly enhanced with the launching of the new generation of the earth resources and environmental satellites, such as the ESA ERS-1, the Japanese JERS-1 and Radarsat during this decade.

SUPPORT OBTAINED FROM MEMBER COUNTRIES AND CO-OPERATION WITH OTHER ORGANIZATIONS

The successful implementation of such a wide range of remote sensing activities has been possible because of the strong support, often in the form of additional funding for high priority tasks, provided by Member countries and international organizations. For example, during the last year the Government of Italy continued its support of FAO remote sensing training courses; the Government of the Netherlands supported the operation and further development of the ARTEMIS system for real-time monitoring of vegetation and precipitation in Africa by environmental satellites; the Government of Japan supported the development of remote sensing inputs to early warning systems for food security in Eastern and Southern Africa; the Government of France supported development of appropriate techniques for applications of high resolution satellite remote sensing data to assessment of land and water resources; the European Space Agency supported development of techniques for agricultural and forestry applications of satellite synthetic aperture radar data and initiated development of the satellite telecommunications system, DIANA, for real-time transmission of ARTEMIS products to their users in Africa. Last but not least it should be emphasized that the work of the FAO Remote Sensing Centre has been greatly assisted by excellent co-operation with the United Nations Outer Space Affairs Division and its Expert on Space Applications.

CONCLUSION

On 8 December 1989 the United Nations General Assembly adopted resolution 44/46 by which it endorsed the initiative of international scientific organizations and bodies to designate 1992 as International Space Year with the theme "Mission to Planet Earth". FAO welcomes this important initiative and will co-operate, within the framework of its mandate and budgetary resources, with our sister organizations and agencies within the United Nations system and with the international scientific organizations and bodies, to contribute to the successful realization of events planned for this momentous milestone in the relatively short but successful history of the development of space technology for the benefit of mankind.

COMMUNICATIONS TECHNOLOGIES FOR DEVELOPMENT*

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INTRODUCTION

These are exciting times. Daily we face political, economic and social changes and challenges. Technology has contributed significantly to this excitement. Consider what didn't exist just a few years ago:

- Semiconductors
- Lasers
- Fiber Optics
- Cellular Radio
- Packet Switching
- Supercomputers

A quote from Camus, an adaptation of an ancient Chinese curse, provides an appropriate introduction to this paper. It reads: "God has condemned us to live in interesting times." To view technology as a curse in these interesting times might cause us to be blind to the opportunities it presents and the contributions it can make to global growth and development.

Below are some comments relating to the adaptation of technology made by leaders from one of the most isolated regions of the world, the thousands of small islands, far from each other and prone to natural disasters, that dot the vast expanse of the Pacific Ocean. I think they are applicable in most of the developing world.

> A communication system can be an instrument of great influence... no one should question the need for a reliable telecommunication service. Links between our islands are virtual lifelines.
>
> Ratu Sir Kamisese Mara
> Prime Minister, Fiji

> The problem is not production, it is distribution. It is absolutely vital that we have better telecommunications. It is costing us dearly in terms of economic development.
>
> Federated States of Micronesia spokesperson

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* This paper, which was presented at the United Nations Workshop on Space Communications for Development, organized in co-operation with the Government of Cuba, Havana, 26-30 March 1990, does not necessarily reflect the views of the United Nations.

If you think in terms of lives lost, then it is not too expensive to provide telecommunications service.

Republic of Belau spokesperson

COMMUNICATIONS TECHNOLOGIES FOR DEVELOPMENT

The benefits of communications technologies have been proven time and again in various developing country studies.

Another example of the role that telecommunications has played is when two whales were stranded in an Arctic ice pack. Through the co-operation of the United States and the Soviet Union, the whales were freed. This costly episode seems to prove that decisions about the use of communications and financial expenditures are not always made on the basis of need but often have political motivations.

Also, a few positive examples across a span of needs which are apt to be common to most developing nations. The Micronesian study of Public Service Satellite Consortium (PSSC) found that, in Ponape, the capital of the Federated States of Micronesia, the Ponape Co-operative maintained an inventory of general supplies (hand tools, tin sheeting, canvas, cordage, nuts and bolts, etc.) worth about $ 1 million. About one-quarter of this was lost annually to both pilferage and natural causes such as rust, spoilage, etc. Once a satellite terminal was installed and reliable telephony, telex and facsimile established, the co-operative was able to cut that inventory down by more than half because they now had timely and accurate information available about shipments coming from Hawaii or the mainland or Japan and could order materials from suppliers in a more timely manner. Returning a half-million dollars a year to an economy as cash-poor as that of Micronesia is a sizable achievement.

Another example involves the use of telecommunications for remote medical diagnosis. About $ 4 million is spent annually throughout Micronesia for transporting patients to off-island hospitals for diagnosis and treatment. Local medical personnel estimate that half this cost is not necessary. If there were adequate telecommunications links for diagnostic consultation, they could handle the treatment themselves. This, too, is a huge sum for a fragile economy and the situation is probably true for many other developing nations.

In another part of the developing world, one might do well to recall Julius Nyere's statement: "While other nations are trying to reach the moon, we are trying to reach the villages." It is possible, through as simple a technology as a single telephone link, to know that one village has a surplus of fish rotting on the docks. It is also short on carbohydrates. Another village, perhaps only 50 miles away, has rotting tubers or yams and a protein shortage. If they were linked in a way that each were unsure of the other's situation, both public health and the economy would benefit.

The objective of this paper is to provide an overview of communications technologies for development. This is in the context of what the world is calling "the micro-electronics revolution." It is also being called the "transistor revolution," "the information revolution" and "the technological revolution."

The fact that so strong a word as "revolution" has come into common use implies that people have felt caught up in forces beyond their control. But "revolution" need not be a negative term. The advanced technologies being developed under the overall rubric of telecommunications have newly defined the word revolution. The next generation of satellites, in conjunction with fiber optics, will open up undreamed of opportunities to meet the requirements and needs of developing nations. This will also be true of the space station and the space platforms of the international Mission to Planet Earth.

There are those who see great benefit in this current situation: many of my contemporaries, particularly from highly industrialized societies, have been conditioned by visions of sophisticated satellites criss-crossing the skies. Some feel that micro-electronics will enable man to shrink his globe to village size. Through the "magic" of electronics, we will all share in the wisdom of the ages and provide universal education, universal literacy and universal good-feeling.

"Global TV" has been suggested by some as an answer to many of our problems. Others are less optimistic; they feel that television is part of the problem, not the answer; that its one-way characteristic lends itself to centralized control and that it is too costly a medium compared to radio, telephony and, especially, new technologies coming on-line.

Before providing some history, in support of Santayana's dictum that "those who do not know history are condemned to repeat it" and some context to the situation in which both developing and developed nations find themselves, a few general comments should be taken into consideration. Out of this workshop, the participants will attempt to translate what is happening in the developed world into specific information about technologies most suitable for the needs and desires of the developing one. This may reveal some personal biases.

First, the impact of television can be a valuable instructional tool which, with more sophisticated production techniques, can make a positive difference in many schools across the United States. However, television has had some negative impacts. Watching it for seven-and-a-half hours a day, the norm in the United States, has destroyed our leisure time. Indeed, had Karl Marx known the medium, he might easily have said that "television" -- not "religion" -- is the opiate of the people.

In some developing countries, the television set has become the most treasured possession. This is true of areas where there is no potable water, no roads or telephones, no electricity (television sets are run by car batteries or by small boys pumping bicycles to power a generator).

Another personal bias regarding instructional television is that motion and colour are not essential to the learning process. Our extensive work with educational teleconferencing has shown that, much of the time, there is no need for the video picture; the job can be done with graphics and alphanumerics using freeze-frame technology. Computers with modems can accomplish virtually the same thing and computers with a camera interface can send and receive any image that can be captured with a camera.

Albert Einstein noted in an earlier age that "Everything has changed, except man's way of thinking." This may have been true when he said it but I would disagree with Einstein in today's context. Attitudes are changing and man thinks and perceives differently because he is better able to communicate. Historically, thinking for many was done by the few who controlled the delivery of messages. Recall printers in Gutenberg's time who were licensed by the Church. With today's satellite broadcasts and small, affordable ground equipment, control over communications can never again be absolute.

The information spreads quickly; it cannot be contained. It seems, however, that there has been, in both the near and far corners of this "spaceship Earth" far more money, time, thought and energy devoted to mechanical gadgets and quantity of data than to the nature and quality of what those are supposed to do for people.

There are in this world, according to the latest figures available through the United Nations Educational, Scientific and Cultural Organization (UNESCO), some 13,350 medium and longwave radio stations; 13,450 FM stations; 1,666 shortwave stations, and 53,890 television stations (counting TV relay stations). The World's Telephones tells us that there are 361,311,758 access lines worldwide. According to the Arthur D. Little Resources Division, an international telecommunications consulting company, the 1989 capital investment in telephones was about $96 billion. A recent United States government paper, just tabled before the meeting of the Asia Pacific Economic Co-operation Group (APEC), stated that worldwide telecommunications services topped $300 billion by 1987 and telecommunications equipment sales, reflecting the growth in services, jumped from $40 billion in 1980 to $109 billion in 1987.

If one adds the installed base of radio and television stations and transmitters, computers, cable and fiber optics, satellites and satellite terminals, let alone other technologies, to the capital investment figure and then compare it to programme and software expenditures, the ratio is overwhelmingingly in favour of the hardware.

In an attempt to put some sense of history, some general ideas, some concerns as well as some sense of what the future holds, the words of a famous humorist provides some insight, "It is very difficult to make predictions, especially of the future." I will also offer some suggestions of the most suitable technologies and services to meet specific country needs. It is preferable to hold back offering prescriptions, after a better understanding of a country's requirements, needs and problems. Any prescription offered, though, is subject to the fact that each sovereign state prides itself on its own autonomy. Despite the uniqueness of each sovereign nation, each country does have common problems and needs. The major difference between developed and developing countries lies in the degree of need and the amount of money available for both hardware and software.

ACCESS TO TECHNOLOGY

While advances in communications technology are dramatically changing traditional work, education and entertainment patterns, many people are unable to gain access to or accommodate changes brought about by the information revolution. They can be called the information poor. They include those with no money; those who are isolated; those who are untrained, uninformed, uneducated; the elderly; the rural; and the migrant. Information poverty exists throughout the world, but like economic poverty, it is most severe among less developed nations, where advanced technology that makes distance largely irrelevant has achieved neither the penetration nor the acceptance found in other parts of the world. The reasons are in some cases purely financial, in some related to shortages of trained personnel, and in some related to matters that can be classified as political. This is why I stress once more that the problems tend to be country-specific although regional solutions are rapidly evolving and will be made even easier in the future through advanced technologies.

There are solutions to be found in aggregating and sharing resources, co-operating and collaborating on planning, making group purchases of hardware or software. In the Caribbean, the Union Latinoamericano y del Caribe de Radiodifusión (ULCRA) has set forth sophisticated plans along these lines.

It is truly both exciting and challenging to contemplate the range of technologies, and the services made possible by these technologies, that are becoming increasingly available to communicators. Each day sees some new advances, some technological "fix" that, at least on the surface, makes the communicator's job easier, increases efficiency, and improves outreach.

Accordingly, these new technologies and services can also have a favourable impact on the costs of carrying out certain tasks. It is difficult to distinguish between technologies and services, especially as computers and communications converge. One should not need to distinguish between them; a truly effective technology (and the services it enables) should be transparent to the user. For the purposes of these comments, and because they are merging at so rapid a rate, I will refer to broadcasting, both radio and television, computers, and all other telecommunications under the one word, "communications."

Primarily, we are talking about the provision of services by common carriers involved in basic telephony, as well as those concerned with distance learning, search and rescue, disaster warning and relief communications, remote diagnostic and other health care, public safety, marine and aviation use, radio and television broadcasting, cable operators, businesses and governmental needs.

Each day's journals report on the battle for channel capacity, however used by broadcasters, cable operators, businesses, providers of services through microwaves and satellites, and telephone companies to reach homes and offices (and people away from both in automobiles, trucks, boats and ships, airplanes, and on foot). Not only are the corporate stakes immense; the public's are as well. Lord Louis Mountbatten put it well and simply: "Science offers us almost unlimited opportunities—but it is up to us, the people, to make the moral and philosophical choices." It is up to us as

communicators to help people make sensible choices and then to realize their potential.

We are moving in this direction. There is a worldwide effort toward the development of a global system using satellite technology to enhance the safety of life at sea and increase survivability in other distress situations. This is a truly international programme. The United States, Canada, France and the Soviet Union jointly developed the SARSAT system which flies on the National Oceanic Atmospheric Administration (NOAA) and COSMOS polar orbiting satellites. Hundreds of lives have been saved by this system long before glasnost. The Search and Rescue Satellite (SARSAT) has demonstrated that countries with diverse ideologies can work together co-operatively for the common good.

Also, computers provide a case-study in national development. Computers have made the rapid spread of information possible and in many instances, affordable. It is really not necessary to point out that information, however acquired, is both power and a survival tool. Those of you who have access to computers and databases will undoubtedly agree with my point. Those of you who don't have access to the tools would, I suspect, also tend to agree.

One example of how the marriage of communications and computers is serving world-wide causes is under the auspices of the United Nations Environmental Programme (UNEP). UNEP's Global Resources Information Database (GRID) is a system designed to provide information to people making decisions that affect the health of our planet. As part of the United Nations, GRID assists planners in their job of managing the Earth's resources wisely and rationally.

With the development of computers that can handle and analyze the immense quantities of information, a global database is now possible. GRID will become a dispersed system with nodes linked by telecommunications. Globally, GRID will be used to make estimations of global trends, such as changes in climate and increasing desertification. Nationally, GRID will be valuable at any stage of planning, from national agricultural schemes to locating roads and human settlements.

It may be instructive to take a walk through the technology landscape. We are dealing with a bewildering and rapidly proliferating number of technologies and if there is a common thread to them, it may be that they are rapidly merging together. I offer this menu not to stun you with what is being written about daily in the technical journals of the developing world, but to make the point that technology seems to be driving us and this may be a good time to sit back and ask if that's what we really want to have happen. One should also be aware of what Lewis Mumford called "the technological imperative: if it can be done, it must be done." Given the bewildering array of possibilities, many of which are being promoted and sometimes aggressively marketed to you as the solution to all your problems--the "universal solvent"--Mumford's fears should be kept in mind.

What follows is a menu with items not necessarily digestible or affordable by all cultures. No matter how these technologies are emerging or

are being put to use, they are seen by some people, in some places, as valuable for meeting certain needs of this information era. It is a very long list. Also, as with most menus, one can order à la carte; one need not order the whole thing when one has limited resources or a small appetite.

Transmission and service technologies currently receiving attention include low earth orbit, direct broadcasting and mobile satellites, Very Small Aperture Terminals (VSATs) and Ultra Small Aperture Terminals (USATs), fiber optics, cable systems, freeze frame/slow-scan television, mobile and cellular telephony, radio and television broadcasting via AM, FM and shortwave, old-fashioned telegraphy and new-fashioned wireless telegraphy, CB radio, amateur radio and low-power television, wireless cable,digital radio, digital PBXs and transmissions, integrated switch digital network (ISDN), compression techniques, microwave, worldwide paging systems, facsimile, packet switching, remote sensing systems, voice-mail, phone-bridges, voice-operated computers and word processors, videodiscs, electronic and satellite news gathering units, audio, video and computer teleconferencing, high definition and advanced television, dedicated network services, data nets, optical discs including CD-ROMS and WORMS (write once, read many times), local area networks (LANS), speech synthesizers, automatic translation, machine reading of printed or typed text, and videotex and teltext.

In developed nations, most, if not all, of these tools are common currency; that is, they are in use on a daily basis. That many are in use, or that they will be used elsewhere is a given, although the exact time-frame is difficult to predict. When it comes to information, there is no difference between the needs of the developing nation journalist or administrator or scientific researcher or doctor, and his or her developed world counterpart. There is, however, a hierarchy of basic needs not being met in developing countries, needs for textbooks, paper, pencils, telephone lines that work. After those needs are computers both for word processing, data manipulation and communications. Needed, too, are adquate transmission facilities, programmes, vehicles, and a linkage between computers and cameras.

Most telecommunications planners firmly believe that no single system--fiber, satellite or microwave--is in the best interest of nations, but that multiple and complementary delivery modes will best serve diverse needs. How many of you have reached the conclusion that the equity question is vital, otherwise, the "haves" get more and the "have-nots" get less?

The developing world is, of course, still grappling with basics; it is amazing to recall how many nations are, for example, still using shortave radio as their primary means of broadcasting within the country despite the fact that, even under the best of circumstances, its quality and reliability are inferior to other technologies available. They have no choice. The International Committee of the Red Cross uses wireless telegraphy, not because it is the best means to deal with disasters, either natural or man-made, but because the areas most prone to disaster generally have no well-developed communications infrastructure in place.

One key, of course, is affordability. The new technologies have been developed in the industrialized nation context and virtually confined within

such countries for their use. Things seem to be changing. Satellites probably represented the first utilization by the developing nations of an extremely high technology that fit, in one way or another, into the context of the above panoply.

EMPLOYMENT OF COMMUNICATION TECHNOLOGIES

However, one cannot look at technologies in isolation. We have studied technological adoption, that process of the acceptance and effective utilization of innovative technology. It begins with awareness and knowledge of the technology. But awareness does not necessarily ensure understanding. Likewise, understanding does not always lead to acceptance and acceptance does not guarantee utilization. It is a process dependent on many major variables such as commitment, politics, advocacy, attitudes, resources, time, training and integration. Other variables include cost, adaptability, competition, reliability and obsolescence. Any telecommunications-related innovation is also subject to a combination of hardware, programme, transmission, logistical maintenance and, most important, human factors.

Thirty-two years ago, we beamed with pride as we launched an inanimate object the size of a grapefruit into orbit. Today, we think nothing of launching objects that weigh just over five tons into orbit. INTELSAT I, launched in 1965, received and transmitted 240 voice circuits on one television channel. INTELSAT VI, launched in 1988, has the capacity for 120,000 simultaneous two-way telephone circuits plus three television channels. And because the International Telecommunications Satellite Organization (INTELSAT) and International Systems and Organization of Space Communication (INTERSPUTNIK)--and International Maritime Satellite Organization (INMARSAT)--are international co-operatives, their services are available to individual developing nations and to regional groupings of developing nations as well. We have also heard there are rumors afoot of a merger between INTELSAT and INTERSPUTNIK which would add another exciting dimension to global telecommunications.

The cost of delivering information via satellite has been dropping steadily. Satellite terminals have been getting smaller and cheaper and some new tariffs have evolved that recognize that developing nations especially will benefit from shared use. The International Telecommunication Union (ITU) has been devoting more time and energy of late to providing technical assistance to the developing world. But they need to be made aware of developing country needs if they are going to meet them. This is also true of INTELSAT, which might be more responsible and move away from its concentration on global beams, which puts the onus on local systems for delivery to isolated and remote locations. While the costs of fiber optic cable and per mile transmissions are dropping, the cost of laying and switching fiber remains excessive for the needs of developing nations; in my opinion, developing countries will be satellite-dependent for some time to come. It is anticipated that new advances by the National Aeronautics and Space Administration (NASA) in onboard switching technology will reduce costs even more for both fiber optics and satellites.

There is one prescription I will presume to offer: political leaders must become aware of what satellite and other telecommunication technologies can do for national development and use the international forums available to

ensure the needs of developing countries are met. In seeking international assistance, those who deal with the World Bank and other fundingsources, both bilateral and multilateral, must be clear about the need to make telecommunications investments a priority matter.

Further, something needs to be done about the tendency, in some nations, to keep telecommunications tightly under control and compartmentalized. This may benefit the national Post and Telephone and Telegraph Administration (PTT) and its profitability but hardly benefits the total society. It is not only the PTTs that are guilty of "hoarding", but the military in the United States is at this moment being asked to give back unused frequencies for the public good because hoarding benefits no one. To restore them, which is obviously more a political than a technological problem, would do a great deal of good. Perhaps, until the equity questions are resolved, we should view telecommunications as a public utility. Ironically, this is happening at a time when the privatization of communications systems is becoming fashionable. You may recall that the right to communicate is enshrined in a series of United Nations resolutions and most countries are taking dramatic steps to ensure that it happens.

Radio may represent the most valuable and underutilized resource for education and communication. In one nation that uses radio as the cement to hold its far-flung islands together, radio must rent some of its facilities from the PTT. The radio station serves a function that in more-developed nations, ones more literate, more homogeneous and with more telephones, might be filled by newspapers or telephony. In this case, radio is mandated to provide education as well as information. Presumably, the PTT is also mandated to serve the public good. Yet, as radio sought to expand its coverage, striving to become truly nationwide, it was inhibited by its lack of funds to pay the compulsory rent demanded by the PTT to put microwave repeaters on existing PTT-owned telephone poles.

Another caveat stems from the need for careful thought and planning in the maintenance and operation of these new technologies. An eminent United States scientist and educator, the late Dr. Carroll V. Newsom, who was deeply involved in broadcasting as RCA's Vice President for Education, noted in the late 1960s:

> With the advent of the communication satellite, the term 'international communications' has suddenly taken on a series of connotations that have introduced to the world a new set of problems of vast complexity and grave consequences. Again we find ourselves dealing with a situation, so common in modern times, wherein technology has outrun man's true understanding of its potential, often potentially disastrous, effects on a society.

Newsom's warning was born out in the course of a study the PSSC conducted of Pacific Basin communications. The study reported that the INTELSAT Pacific satellite carries some United States--and other--television programming in transit to Australia and Japan, and to a select number of other Pacific Rim countries. Each of the islands had a satellite terminal. The islands did not have television. It became apparent that some satellite earth

terminal stations were receiving broadcast television, mostly United States programmes at different hours. These programmes were often being viewed by technicians and by others "in the know."

For this to have happened, it was necessary for those in charge of the earth stations to have deliberately repointed them away from the primary path bird and "looked at" the secondary. Harmless diversion? While this was happening, all telephone, telex and other record carrier traffic was not receivable. Suppose there had been a typhoon warning. A medical emergency. A disaster of some sort.

This is in part what Newsom alluded to—and I would call it to the attention of communicators and especially those with management responsibilities. The mind-set of those who were operating the satellite antennas was such that they did not foresee the consequences of their action. Their technical skills may have been sufficient but this situation argues for another set of skills as we permit perople to operate equipment of increasing power, complexity and capabilities. There is a moral component that must be built in. This may be the hardest management or self-learning job of all, since it implies acquiring respect for that power and capability and a sense of one's duty as the custodian of it.

IMPLICATIONS

There are some other implications to the use of satellite and communicators are increasingly using them. They speed up the process of interconnection between one place and another or one place and many; that is, satellite-transmitted events and information are often in real time; this is one of their great values. The communicator, especially if a broadcaster, on the receiving end must make split-second decisions as to what to carry and what not to carry, and often those decisions must be made in a political and cultural context. Satellites also reach out-of-the way places and, in some instances, places that are video-illiterate. Here, too, a degree of cultural sensitivity is called for, perhaps over and above the operation of a radio or television station using pre-taped programming.

My argument is that knowledge of the technologies and their use and value is not sufficient. We need, in this "brave new world," this "Global Village," also to be aware of societal implications and culture and tradition. This seems true of software as well. The person making decisions about the choice of technology to acquire must have some sense of the power of the tools, both positive and negative. Where there is a risk, the decision-maker must be prepared to accept the consequences.

In summary: we are in a period of ferment. Technologies are being developed, put in place and used at an increasingly faster rate than, perhaps,at any other point in history. Telecommunications, including telephony, broadcasting, remote sensing and computing, are converging. The knowledge and understanding required to deal with any one of these elements alone is a difficult task to achieve; understanding and dealing with the combined effect, the gestalt, is even more difficult.

The key is that while people need to know what they are doing technically and programmatically, they must also know what they are doing in terms of

social and moral responsibilities. This is a difficult task, but it is of primary importance.

Despite some reservations about offering prescriptions, let me be presumptuous enough to make some observations. It is doubtful that fiber optics will, in the foreseeable future, solve many of the problems of developing nations. It is a not-inexpensive technology and requires a high capital investment, especially if one is politically committed to a system which provides as close to universal service as is possible. Cellular and mobile telephony, both terrestrial and satellite, can be more quickly mounted and implemented. Those favouring fiber optics as a universal panacea tend not to be concerned with the problems of the poor, the rural and the isolated. Services to such areas for a long time to come will better be met by satellites.

Fiber optics have experienced some other problems. On the lighter side, its outer coating has become a favourite food for sharks when laid underwater, the submarine equivalent of the tendency, in certain African countries, for giraffes to knock down overhead telephone and telgraph wire and baboons to chew happily away at its insulation. More seriously, it is known that, on numerous occasions, INTELSAT has had to take over the traffic from the transatlantic fiber cable when it failed. Most of the fiber companies have contracted with satellite carriers for back-up services.

DELIVERY OF COMMUNICATIONS TECHNOLOGIES

What of the future and the Caribbean region's needs? Many of the technologies are still in the process of coming on-line. Even more esoteric ones, mostly in the computer field, are on the drawing board, such as optical computer, artificial intelligence, parallel processors, even biological computers. Computing and communicating will probably both become less expensive as time goes on. Databases and databanks will proliferate and the new communications technologies will make remote access to them easier.

There is clearly a worldwide trend away from state monopolization of communications facilities and, in some instances, competition may drive down costs. For example, Mexico is about to sell its telecommunications system and Moscow has accepted commercials and is about to open a private radio station. Also, bypass, the ability to circumvent the public switched network, is a reality. Audio cassettes fueled the Iranian revolution; facsimile transmissions poured news into China during the student unrest in 1989; wherever there is international direct dialing—now possible in 150 countries—and there are computers and modems, barring transborder communications is no longer a possibility; they cannot be controlled or policed.

As personal communications technologies become smaller and cheaper, each citizen acquires sovereign rights. This has been true of reception technologies for a long time; one need only look at the 16,000 television receiving earth stations (TVROs) in Chihuahua, Mexico and the large number of Chicago Cubs fans in Belize who can pick up the games aired via satellite by a superstation in Chicago. This is reception technology; history teaches us that transmission technology is not far behind.

In some instances the merger of technologies, such as that of the computer and telecommunications, is an ideal marriage; in some, a marriage of convenience, because each of the technologies has different strengths and weaknesses. It may very well come about, for example, that satellites will carry the bulk of transoceanic television traffic and fiber will pick up and relay the signal to certain areas. Domestic satellites, combined with cellular or mobile technologies, will carry the message the final mile, or some variation of the above. The final mix of how messages are carried will problably vary globally, regionally and within countries.

There will be useful low-earth orbiting satellites, capable of transmitting electronic mail and data using burst transmissions and a store-and-forward messaging technique linked to microcomputers. The information doesn't arrive in real-time, but it does arrive. This will give new meaning and new utility to packet broadcasting. Mobile and cellular telephony may save you millions in wire costs. Satellite audio-broadcasting to inexpensive home receivers may allow you to replace obsolete ground-based transmitters at an affordable cost, especially if the delivery system is to be operated by an international common carrier, or international co-operative or consortium, where you need only rent the capability you need. VSATs and USATs are proliferating and the costs are dropping.

The new generation of satellites exemplified by NASA's Advanced Communications Satellite (ACTS) will have higher power on-board as well as the ability to address, through hopping spot beams, a single location or at many locations at once. ACTS, utilizing the Ka-band frequencies, is designed to incorporate a set of new technologies that will make the transmission of voice, video and data more efficient and cost-effective. Among these are higher frequency, broader bandwidth, on-board switching, hopping spot beams and steerable antennas. ACTS-type technologies in an operational system will provide up to 2500 MHz of capacity in contrast to 500 MHz in C-band and Ku-band. The flexibility for its use in remote and rural areas is far greater than that of fiber optics. Hopping spot beams also enable frequency re-use. By making better use of the finite resource radio frequency spectrum, you will use only what you need and pay only for what you use. Because of this, a new range of telecommunications services will be available to rural areas, including health care techniques like medical imaging. Also, businesses will be able to locate outside of costly urban areas and still have the communications capacity they need. Furthermore, developing countries will be able to leapfrog into these useful new technologies because they do not have to recover the cost of capital investments in older technologies.

There will also be combinations of many of the technologies which will most likely develop because they fit individual nations' needs, or the needs of a region or regions. It is even probable that manufacturers, who have concentrated on making large and costly equipment for use in developed nations, will begin to perceive the huge size of the market in the developing world and begin to design hardware that is smaller and cheaper, and more appropriate. There are some hopeful signs in this direction. Just as with computers, the ground systems for satellites have smaller packages, more capacity and at less cost.

The development of technologies that can be used should not only be urged upon the world manufacturer community, but might be urged upon the local government in helping to ensure that their use is permitted by international regulatory bodies and each country's own PTTs.

CONCLUSION

This presentation can be concluded with a quote from an eminent scientist, Dr. Jay Forrester: "There seems to be a common attitude that the major difficulty is a shortage of information and data. Once data is collected, people then feel confident in interpreting the applications. I differ on both these attitudes. The problem is not one of the shortage of data but rather our inability to perceive the consequences of the information we already possess."

As stated in the beginning of this paper, these are interesting times. It is hoped that those of us with the heavy responsibilities of communicators or communications managers can keep on top of what we are doing as the tools of the trade become more powerful and sophisticated. And it should be remembered that these are tools that we must employ for the benefit of our societies in their totality. "The Global Village" is not a one-time television spectacular with rock stars, aired to capital cities with television; it is a state of reality to be achieved through worldwide co-operation.

A RURAL COMMUNICATIONS NETWORK FOR HEALTH CARE DELIVERY*

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INTRODUCTION

This paper will briefly review the history of telemedicine/telehealth and will emphasize developments in Canada. The experience at Memorial University of Newfoundland will be presented. Due to the geography and demography of the University, there has been a need to develop communications links with remote communities in the interest of programmes in education and health.

Since the invention of the telephone, telecommunications has played an important role in health care. Wireless and ship-to-shore radio have been in use throughout much of this century. Organized telemedicine, defined as the use of telecommunications in the support of health care, has been developed in the past 20 years paralleling the peaceful use of space. While some terrestrial experiments were conducted about 25 years ago, it was the rush to outer space that resulted in the development of a number of satellite health projects. Largely from these experiences came the current activity, much of which is terrestrially based. Satellites, however, provide the only reliable links to some rural, isolated and remote areas.

For the Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space, held at Vienna in 1982 (UNISPACE 82), Canada made a presentation that consisted of a live demonstration by Memorial University of Newfoundland. This was a one-way television, two-way audio link between St. John's and Vienna. The programme included a discussion and demonstration of Canada's experiences with satellites in the fields of health, education and social applications.

THE MEMORIAL UNIVERSITY EXPERIENCE

Canada was the third nation to enter the satellite field and in 1976, jointly with the United States, built and launched the high-powered Communication Technology Satellite (CTS) or Hermes satellite. Memorial

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* This paper, which was presented at the United Nations Workshop on Space Communications for Development, organized in co-operation with the Government of Cuba, Havana, 26-30 March 1990, does not necessarily reflect the views of the United Nations.

University participated in the Hermes experiments with a three-month project consisting of a one-way video, two-way voice link with four remote communities and the University. From these experiments, health education, data transmission and administrative applications were evaluated.

While this project demonstrated the effectiveness of television for remote health care, it was concluded that live television would be impractical and would be a prohibitively expensive method of operating a multi-point telemedicine system. It was also concluded that much of the educational content could be effectively delivered by an inexpensive narrow band telephone system. Since 1977, the Telemedicine Centre has directed its efforts towards research and development utilizing interactive audio networks to distance health and education needs of the province.

Rural Communications

The Teleconference System (TCS), which was started in 1978, is a dedicated 4-wire audio system. It is a province-wide network consisting of five separate divisions. These divisions can be combined as required or used separately for multiple, simultaneous programmes. The network now has 170 sites in approximately 80 communities throughout Newfoundland and Labrador. There are installations in all hospitals and some clinics, in all the community colleges, university campuses, a number of nursing stations, town buildings, some high schools and in many government offices. A number of health and educational agencies are linked to the system.

The Teleconference System carries a variety of health education programmes for physicians, nurses and other health professionals. There are also community health courses. Various government departments use the network for administrative and for coordinating and training sessions, e.g., all social workers can be brought together by teleconference to discuss changes in the welfare act or new procedures for clients.

In addition to the major province-wide dedicated and 4-wire network, the system includes a 20-port teleconference bridge to accommodate conferences involving individuals or groups not on the network. This bridge facilitates conferences involving other parts of the world.

Medical Data Transmission and Video Add-On Technology

The functions of the ordinary voice network have been greatly enhanced by the addition of technical equipment including slow scan television (SSTV), electroencephalogram and electrocardiograph transmission and telewriters. More recently electronic mail and facsimile transmission are being used.

Electrocardiogram (ECG)

An ECG service operates between remote sites and central sites. At present, six locations in the province have transmission equipment. Considerable expansion of this service is anticipated.

Telewriters

The telewriter is, in effect, a combination of hardware and software which turns a personal computer into a distance blackboard. The modems that accompany the unit are designed to permit simultaneous transmission of voice and data along a single telephone line. Freehand writing and computer graphics can be exchanged, annotated, altered or discussed during a conference. Instructors and students use a pen to write on a graphics tablet. The message is instantaneously received at all "classroom" sites and displayed on monitors. At present, these units are used almost exclusively in the education setting and are of particular interest to instructors in science, math and research-based courses.

Slow Scan Television

The Telemedicine Centre began its experiments with slow scan television (SSTV) transmissions in 1977 when a limited series of X-rays were transmitted via the HERMES satellite from a remote hospital to a central hospital. Although radiologists had some difficulty reading the X-rays due to artifacts, the Centre was encouraged to continue its experiments with the technology.

During later trials between 1979 and 1983, a clinic on an offshore oil drilling rig was linked to the emergency department of a tertiary care hospital using dedicated audio channels on Canada's Anik B satellite. SSTV equipment was used routinely to supplement the audio link for patient consultations between the rig medics and onshore physicians. Transmissions were largely of patient lesions. Both medics and physicians were satisfied with the quality of transmitted pictures. The petroleum company later installed equipment on both its operational rigs in the region and commercial satellite channels which are used on a dial-up basis whenever consultations with physicians are required.

Due to the fact that the rig did not have X-ray equipment on board, films were sent to the rig for transmission and interpretation by radiologists as part of the trials. Artifacts noticed in previous trials have been dramatically reduced. The technology provided sufficient resolution to allow adequate interpretation of X-rays. Radiologists were, and continue to be, more confident of their findings with bone films than with soft tissue films.

The Centre has also used slow scan transmissions in its shared programming with the University of the West Indies network (UWIDITE).

The Telemedicine Centre is currently developing a tele-radiology (tele-imaging) project. Digital slow scan units are being acquired for two rural and remote hospitals. Ultrasound and X-ray images will be transmitted from one hospital and CT images from another. The slow scan equipment will also be used to support remote consultations in neurology, psychiatry and rheumatology.

Computers

The teleconference system is not used for conferencing between the hours of 10 p.m. and 8 a.m.. To maximize the benefit of this dedicated facility for

a user consortium, a software programme has been developed to permit an automatic electronic mail (E-mail) service between computers at sites on the dedicated system. It is anticipated that this service will be utilized both for exchange of medical test results and programme materials.

INTERNATIONAL PROJECTS

In the last five years the Telemedicine Centre has been privileged to participate in a number of international communications projects. These included links to Kenya and Uganda in East Africa, Aberdeen, Scotland, and Jamaica in the West Indies. These projects have fostered the further development of more extensive international links. Demonstrations of Telemedicine have been given in a number of countries, including Argentina and Brazil.

Africa

During 1985 and 1986 the Centre was approved to participate in the International Satellite Organization's (INTELSAT) Project Satellites in Health and Rural Education (SHARE). As a celebration of its 20th anniversary, INTELSAT made satellite services available free of charge to approved experimenters who wished to offer health or education programmes in developing countries.

Memorial's project had two components. The first utilized a dedicated four-wire audio circuit to link the medical schools in Kampala, Uganda and Nairobi, Kenya with the Medical School in St. John's, Newfoundland. The link was utilized approximately three hours a day for medical teaching, administrative purposes and medical data transmission. As Kampala did not have a functioning EEG department during the trial, four EEGs a week were transmitted to the EEG Department at the Health Sciences Centre in St. John's. Faculty of other Canadian and international universities were regularly linked to conferences via the dial access capability of the Telemedicine bridge. These activities were part of an overall project Child Health and Medical Education Programme (CHAMP). The objective of that project was to assist in the rejuvenation of the Kampala Medical School through the establishment of an active primary health care unit based on maternal and child health.

West Indies

The second component of the Centre's SHARE project was a link between Memorial's teleconference network and the University of the West Indies, Jamaica. During this nine-month project a variety of programmes were shared and an ongoing liaison between the two networks was planned. As a result of a proposal developed during Project SHARE, Memorial and the University of the West Indies have been funded in part by the Canadian International Development Agency to:

(a) design and implement a radio-based teleconference network within Jamaica that could be interfaced with the existing University of the West

Indies Distance Education Experiment (UWIDITE) network or operated separately;

(b) broaden the programme base of both the UWIDITE and intra-Jamaican systems; and

(c) develop a variety of shared programmes between the two universities.

United Kingdom

The Telemedicine Centre carried out a joint tele-radiology trial with the Robert Gordon's Institute of Technology and Aberdeen University in Scotland in 1987.

SatelLite

SatelLife is a non-profit international organization committed to using modern communication technologies to link medical centres and physicians throughout the world providing critical information. SatelLife, with an international board of scientists and physicians, is an East-West partnership with offices in Boston and Moscow. The board has four American, four Russian, one Canadian, and one United Kingdom member.

Memorial University will be participating jointly with SatelLife in one or more projects. The first project will see a link between Memorial University in Newfoundland and a hospital in Uyo, Nigeria. This link will be by a low altitude, orbiting satellite. This packet satellite will provide communications by a combination of an established technology and a newer technology (radio, microcomputer and modem).

The earth station will be a lap-top computer connected to a radio transmitter/receiver. The satellite passes over a given point on the earth twice daily. There will be an 18-minute "window" during which time information will be received and sent to the satellite with delivery to other transmitting/receiving stations anywhere in the world. Obviously, the applications will be in areas where no communications system now exists.

SALIENT POINTS

There are a number of audio teleconference networks in Canada, the United States and other countries, e.g., New Zealand. These vary in type and size but basically use inexpensive telephone circuits. Some use ordinary telephone conference facilities similar to a "conference call." Others have dedicated networks similar to TCS. Others have their own teleconference bridges.

By combining these bridges it is possible to have large group meetings. For example, Newfoundland physicians and laboratory technologists participate in meetings of the American Society of Clinical Pathologists, with the total number of participants in about 15 centres in North America amounting to more than 700.

Various health groups have held a number of successful international two-way interactive video teleconferences. While these are appropriate for special meetings, they are expensive and the cost of a regular series of such conferences would be prohibitively expensive unless some of the facilities were free.

We have found that live television is not necessary for successful teleconferencing. Voice-only supplemented by telewriters, electronic mail and facsimile (FAX) are highly effective. Live television can add substantially to user satisfaction, but is not necessary for a given health project to succeed. Where necessary, videotapes can be made and circulated to participating sites.

Worldwide organizations and agencies could set up audioconference networks between countries. Using a simple audioconference bridge, it is possible to link a very large number of countries if necessary.

Within any country, limited only by the availability of an ordinary telephone system, many points can be linked together and those in turn linked to an international network. The financial success of such a network might depend on a number of users sharing the facilities. Any non-profit health, education or community agency might share such a project.

With the addition, where needed, of telewriters, computers, slow scan television and FAX machines, the use of more expensive live television would be required only when it was essential to a given major conference or for countrywide broadcasting.

Given the many problems facing the world, such as acid rain and other environmental problems; recurring famine; disasters; and, the need to share learning resources and expertise, a simple, inexpensive international teleconference network could be developed as a further step towards the "Global Village" concept of Marshall McLuhan.

CONCLUSION

Inexpensive audio systems using ground-based or satellite networks can be used to deliver distance education and telemedicine services. "Add-on" equipment such as telewriters, slow scan television and computers can enhance the effectiveness for both teaching and health care. The transmission of medical data such as EEG, ECG and X-rays provides expertise usually found in more urban areas to remote and rural communities. Community health education programmes are being successfully delivered by telecommunications.

DESIGN, IMPLEMENTATION AND ACCESS VIA SATELLITE TO TELECOMMUNICATIONS STATISTICAL DATABASES ON MICROCOMPUTERS*

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INTRODUCTION

Exchange of information stored in computer memories involves, in addition to computer hardware and software technologies, data transmission techniques and, for long distances, often satellite communication services. Due to the fact that the transmission quality must be very high, sophisticated digital techniques are used at various stages of the transmission route. The access to Telecommunication Statistical Data Bases (TSDB) on microcomputers can be very useful to the analyst for updating or retrieving information in or from remote data banks.

COMPUTERS AND TSDB

A computer is an efficient means to store data in a data bank and to retrieve data when necessary. Applications for banking, hotel or travel booking are well-known. In these cases, however, most of the data are stored in large centralized computers and the microcomputers are needed for the access to these high capacity data banks through a dedicated data network or through the public telecommunication network. Continuous improvements in microcomputer hardware and software, however, have made the realization of TSDB particularly attractive in the telecommunication environment. This has provided for considerable reduction in the development time of databases and creation of efficient links between data management and data analysis.

The low cost of microcomputers coupled with the availability of relatively inexpensive, user-oriented application packages made them an attractive option for supporting telecommunication analysts' requirements. Simple database systems such as D-base and spread sheets such as Lotus 1-2-3 and Excel are used to store data. These systems, however, also have their limitations. Although the latest generation of microcomputers are capable of storing millions of characters of information in their memory, the Disk Operating System (DOS) only allows a limited amount to be accessed.

The DOS memory constraint affects the development of multiple access to data because both the database and supporting network software compete for the

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limited amount of memory provided by the operating system. Recognizing the limitations of DOS, the computer industry has recently released a replacement, Operating System 2 or OS/2. This system provides virtually unlimited memory as well as other features that exploit the power of today's microcomputers. Hopefully, it will soon be used to improve the multiple access and user comfort.

In the International Telecommunication Union (ITU) several databases are available in different locations. There are a number of refinements to be considered to improve the access to these data. Database software and the local network will be used to provide efficient multiple access to these different databases, in a first step only internally. A pilot project known as the Telecommunication Exchange Services will allow external users to access ITU databases.

INTERCONNECTIVITY

To implement a universal compatibility between computers, computerized equipments, and communication networks, the International Organization for Standardization (ISO) in Geneva, has developed the Open Systems Interconnection (OSI) Model, which is a framework for defining the communication process between systems. This Reference Model defines the functions involved in communicating and the services and the protocols 1/ required to perform these functions.

Many of the protocols associated with the OSI Model have been defined to incorporate existing standards (i.e., the digital CCITT X.21, the CCITT X.25, and the IEEE 802 for local area network (LAN), etc.) which are already widely implemented. Others are aimed at meeting the likely future requirements of international telecommunications. In particular, ongoing work on the integrated services digital network (ISDN) is closely related to work now taking place in OSI.

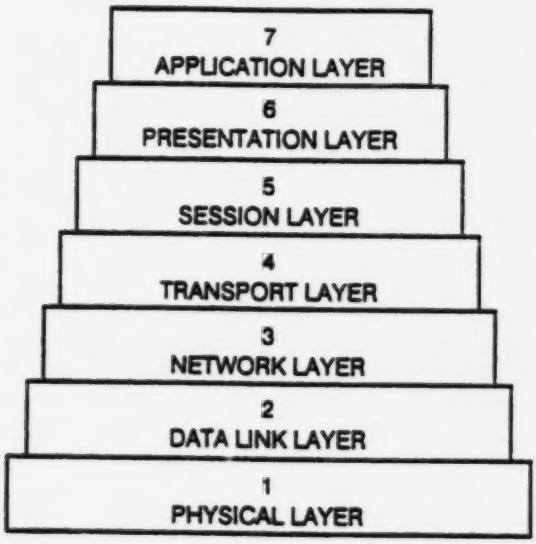
A layer structure

The OSI Reference Model, the structure of which is presented in figure 1, breaks the process of communicating into an orderly sequence of seven layers. It was adopted by the ISO in 1984.

Viewed as a system, the layers of the Reference Model can be split into two groups. The bottom three layers - physical, data link, and network - cover the components of the network used to transmit the message via satellite, X.25 network, or Local Area Network (LAN). The top three layers - application, presentation, and session - reflect the characteristics of the communicating end systems, regardless of the physical means actually used. The transport layer acts as a liaison between the end systems and the network.

Service concept

At each layer of the Reference Model, there are services to carry out the functions. For instance, a service such as requesting initialization is needed to initiate the control function for a conversation between two end



Structure of the OSI Reference Model

Figure 1

systems. When an application process initiates a communication, it passes its message down through each layer. The functions of each layer add value by providing services which enable the communication to be completed.

The main feature of OSI is that these service definitions are independent. In other words, every service can be implemented regardless of the methods used to implement services in the layers above and below it. Error checking, for instance, may be provided in different systems by dissimilar devices or software. As long as the devices or software use the same approved protocol, it will perform the same function for the end-user.

The ISO specifies protocols for each service definition within the layers of the model. These are descriptions of the bit coding formats in which specific information is passed between processes, as well as the procedure to interpret it. Protocols operate between the same entities (the parts of a system providing services for a given layer) of the end systems. For example, information about a network layer protocol in a message sent by a system is used only by the network layer in the receiving system.

Data processing

The message from the application process plus information added by each layer below form the frame that is sent out over the network (see figure 2). At each layer, header control information is appended to the data unit received from the layer above. This information identifies the protocol options used and gives other data about the message and its routing.

At the receiving end, the header information is removed and processed by each layer. The remaining data unit is then passed up to the next layer, where a similar operation takes place.

Message routing

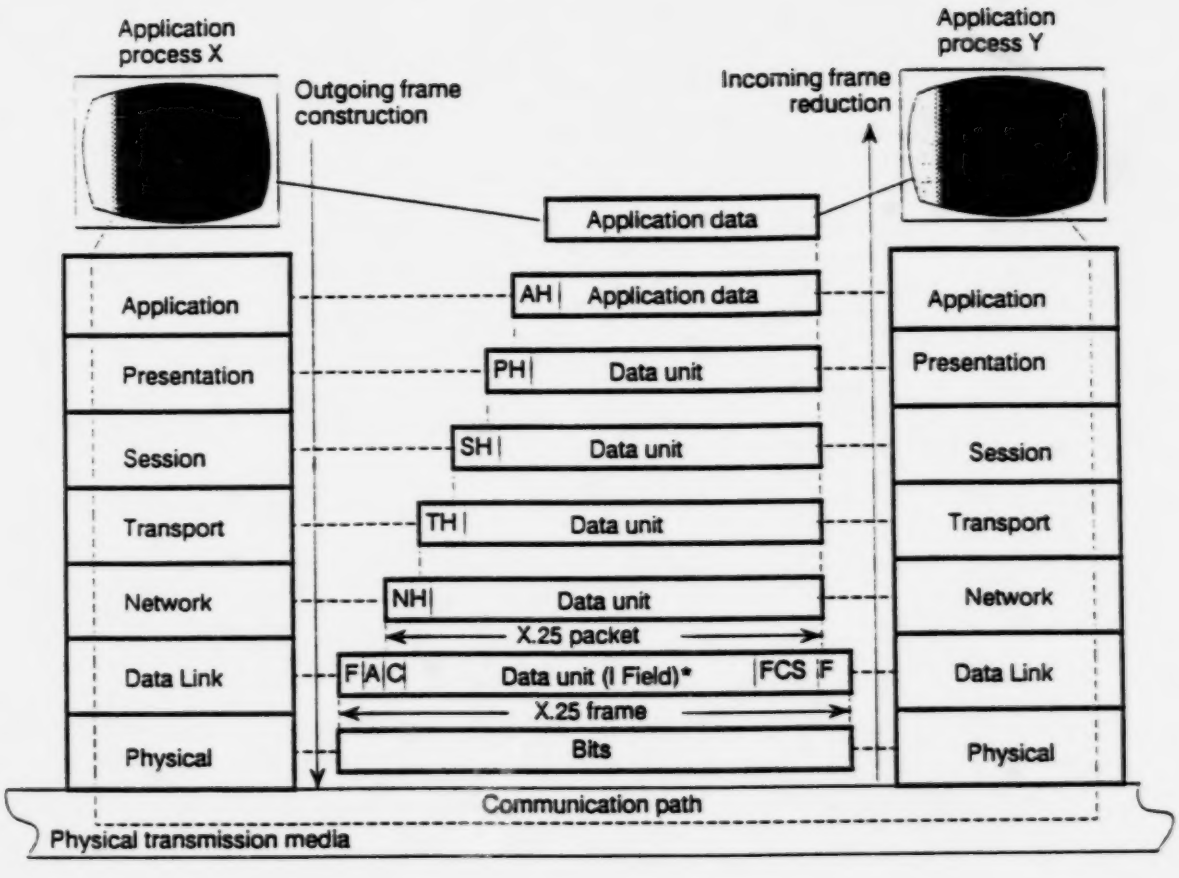
Data routed between networks, or from node to node within a network, requires only the functions of the three lower layers: network, data link, and physical (see figure 3). The network node is called a relay system. A message may pass through many relays on its way between the application processes. In an OSI application, the path taken is invisble to the end-users. Only relay systems know what route a message is using.

Physical layer

The bottom layer of the Reference Model, layer 1, is called the physical layer, or the interface with the physical medium. It includes the functions to activate, maintain, and deactivate the physical connection.

Data link layer

Layer 2, the data link layer, formats and synchronizes the messages. It provides error control for the information transmitted through the physical link. Layer 2 protocols break up the stream of data into frames which are transmitted sequentially. A frame acknowledgement signal is required from the receiving system. If this signal is not received, the frame is then

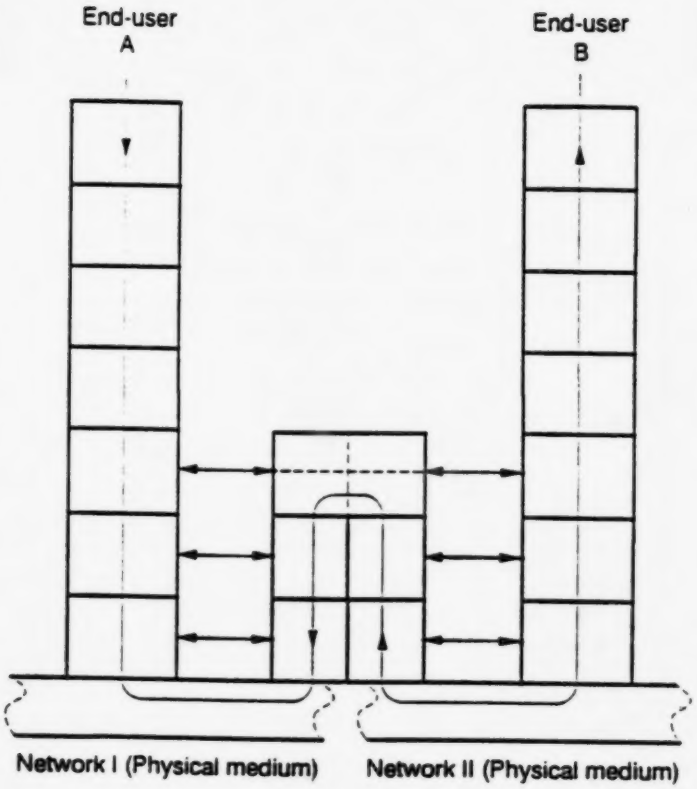


Data Processing

* The head and the data link level are in compliance with the CCITT Recommendation X.25 frame format:

F: opening and closing flag
A: address
C: control
FCS: frame check sequence
I : information
H : header

Figure 2



Message Routing

Figure 3

retransmitted. The data link layer also provides flow control - monitoring the rate of frame transfer - so that systems can exchange data at different speeds.

Network layer

Layer 3 is the network layer. Its functions include routing communications through network resources to the system where the communicating application resides, and some error correction. The network layer acts as a network controller by deciding where to route data, either out along a physical network path or up to an application process.

Transport layer

The transport layer, layer 4, includes such functions as multiplexing a number of independent message streams over a single connecting and segmenting data into appropriate sized units for efficient handling by the network layer. It also provides end-to-end control of data reliability. Several classes of protocol are specified, from the simple class, for use with highly reliable X.25 networks, to the high quality class with error detection and recovery, for possibly unreliable networks.

Session layer

The functions of layer 5, the session layer, are to manage and synchronize conversations between two application processes. This layer provides two main styles of dialogue: two-way alternating (half-duplex), in which two parties alternate in sending messages to each other, and two-way simultaneous (full-duplex), in which two parties may send and receive data at the same time.

Presentation layer

Layer 6, the presentation layer, ensures that information is delivered in a form that the receiving system can understand and use. The format and syntax of messages are determined by the communicating parties. The functions of the presentation layer can, if required, include translation. For example, if one application process transmits a file in a given code, while the other end uses another code, the two sides will negotiate which encoding to use and which side will perform translation.

Application layer

The top of the Reference Model, layer 7, is the application layer. It provides services directly to the application process: resource management for file transfer, virtual file and virtual terminal emulation, distribute processing, etc. It is the layer that will contain the most functions and the one in which the widest variety of work will be done.

DIRECT CONNECTION OF SATELLITE DATA NETWORKS TO USER EQUIPMENT

General

Satellite communications now find important applications for directly connecting Data Terminal Equipment (DTE) installed at the end-user's premises to a main computing or data processing facility (the "host" computer). Such applications ("business or corporate data communications") are usually operated in the framework of dedicated satellite networks which can be substituted for terrestrial data networks.

For access to telecommunications statistical databases, the modest level of data exchanges would not justify a dedicated satellite network and the public switched international network or private satellite networks could be used. However, the principles governing the technical implementation of the data exchange system remain the same.

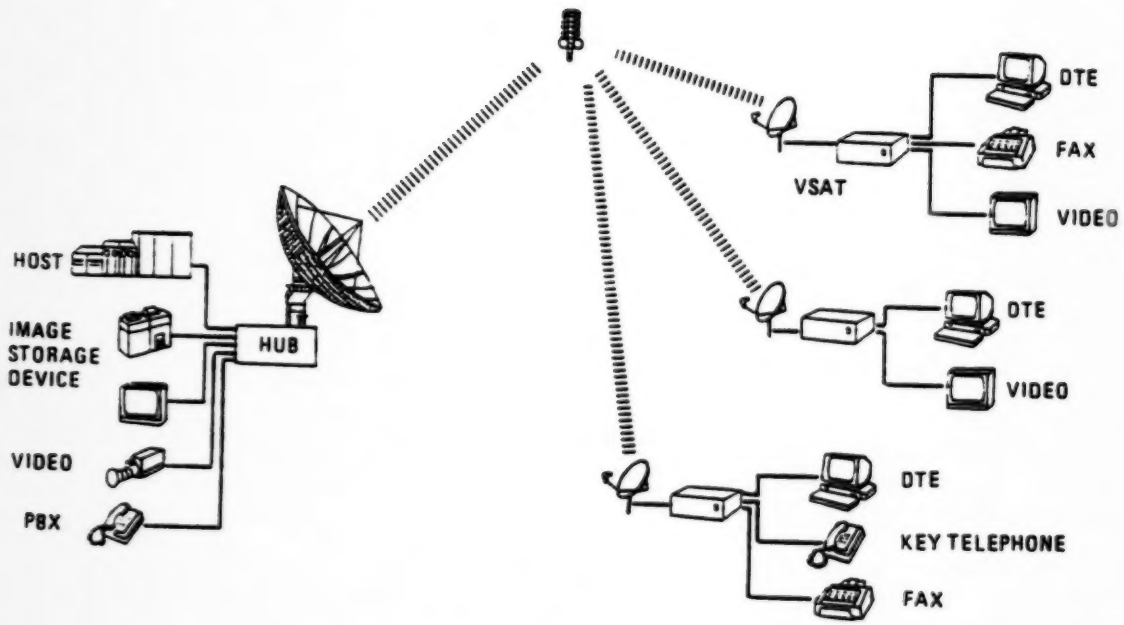
In most data networks, information is transmitted by grouping the data into "packets" ("packet orientated networks" or "packet switched networks"). 2/ In consequence, satellite data networks will generally use this mode just like their terrestrial substitutes. Also, in modern networks, the process of communicating is separated into an orderly sequence of software procedures called "layers" or levels, as described in the preceding chapter.

The general scheme for connecting user equipment according to this layered protocol approach (within and outside the network) is represented in figure 5: the user DTE communicates directly with its local DCE (Data Circuit Terminating Equipment) and indirectly with the remote DTE. DTE to DCE communications use layers 1 (physical layer), 2 (datalink layer) and 3 (network layer) to exchange data. DTE to DTE communications rely upon the services provided by the lower layers (1 to 3) and use layers 4 to 7 for end-to-end communications. The gateways perform the translation process between the internal network procedures (i.e., DCE to/from DCE) and DCE-DTE exchange procedures.

In Europe, most of the modern terrestrial data networks (which are often public networks) are packet switched data networks (PSDNs) using International Telegraph and Telephone Consultative Committee (CCITT) Recommendation X.25 at the network interface (e.g., Transpac in France, Datex-P in Germany, Itapac in Italy, Datanet-1 in The Netherlands, PSS in the United Kingdom, etc.). In the United States, although many applications currently use other protocols (e.g., IBM's Binary Synchronous Communications (BISYNC) or Synchronous Data Link Control (SDLC)), these X.25 interfaces will probably be more and more used in the future.

VSAT networks

This section is more specially concerned with the case of satellite data networks using microstations, also called Very Small Aperture Terminals (VSATs), at the user's premises and a star architecture with a central station (the "hub" station) at the host location (see figure 4).



"VSAT" Network

Figure 4

The VSAT network operation and management is usually controlled by a Network Control Centre (NCC) which can be located at the hub. Current design of VSAT networks offers performance similar to existing terrestrial data networks and utilizes the most common user-network interconnections and interface protocols. The fact that VSAT networks operate internally in the packet mode does not limit users to packet orientated communications because packetizing functions can be performed in the interfacing units of the VSAT terminals. VSAT networks may also offer significant additional advantages as they are more easy to install, especially in isolated areas, than terrestrial systems.

Applications of VSAT networks include centralized stock control, credit card verification, ticket reservation systems, etc. For example, communications in the stock control application would normally be initiated by the host computer which polls the remote terminals periodically for stock updating. Other applications use an important feature of VSAT networks which is their ability to broadcast information from the hub to all VSATs or to a group of VSATs through an appropriate addressing scheme.

Referring to figure 5, the signal processing terminal of a VSAT forms the local DCE at one end of the network. At the other end, the DCE is formed:

- either by the hub signal processing terminal for communications between a remote terminal (VSAT) and the host computer in the hub; or

- by the signal processing terminal of another VSAT if a VSAT-to-VSAT (double hop) operation is permitted by the general network design, i.e., is provided for in the NCC.

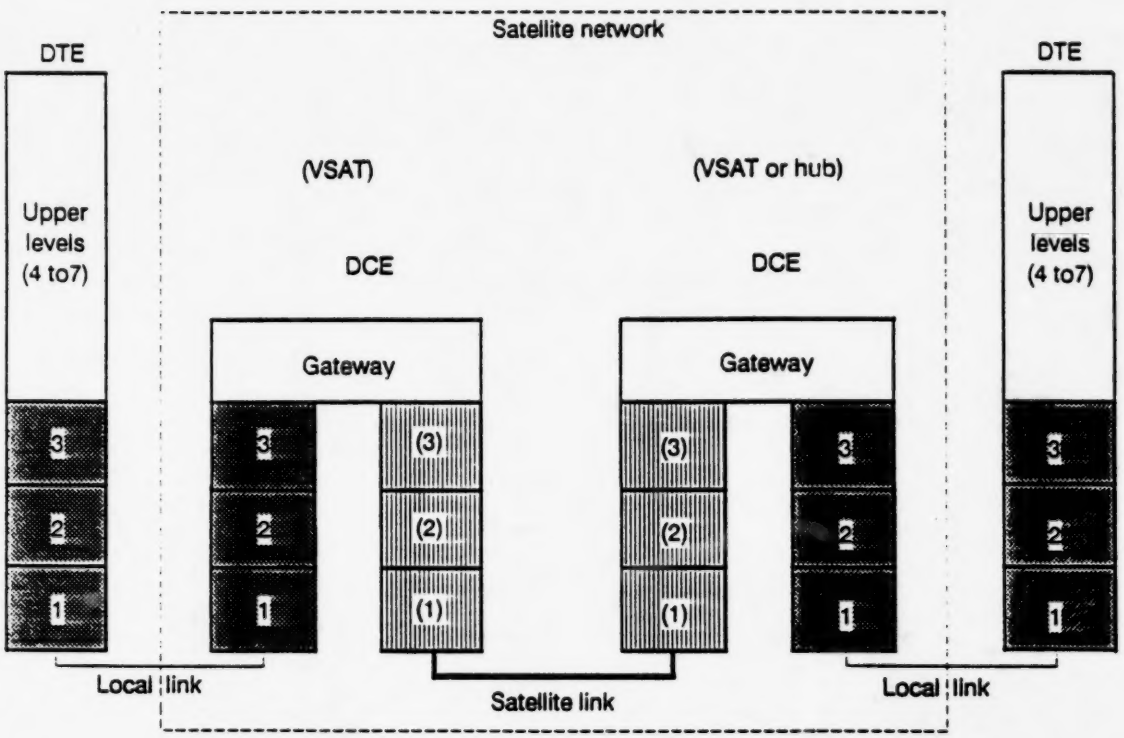
One consequence of implementing packet switched processes in VSAT networks is that the "packetized" information is structured in formats containing error detection codes which can reject each erroneous packet, i.e., each packet where even a single bit is transmitted with an error.

Figure 6 shows the system block diagram for a typical VSAT station working in the single channel per carrier (SCPC) mode. In figure 7, a small earth terminal is shown, and figure 8 represents a typical hub station.

DATA TRANSMISSION OVER SATELLITE

In satellite networks linking VSATS, the Single Channel Per Carrier (SCPC) technique is generally used. The transmitted data rate is in most cases 64 kbit/s or a multiple of 64 kbit/s. Several data streams can be multiplexed (mixed) on a single channel. A VSAT can transmit more than one SCPC. The hub station generally transmits several SCPCs simultaneously.

A typical power level diagram for a 64 kbit/s link between two 2 m antenna earth stations is given in figure 9. Levels for a link between a 2 m antenna earth station and an 11 m hub station are also shown.



Layer representation of user to user data communications (e.g. CCITT X.25)

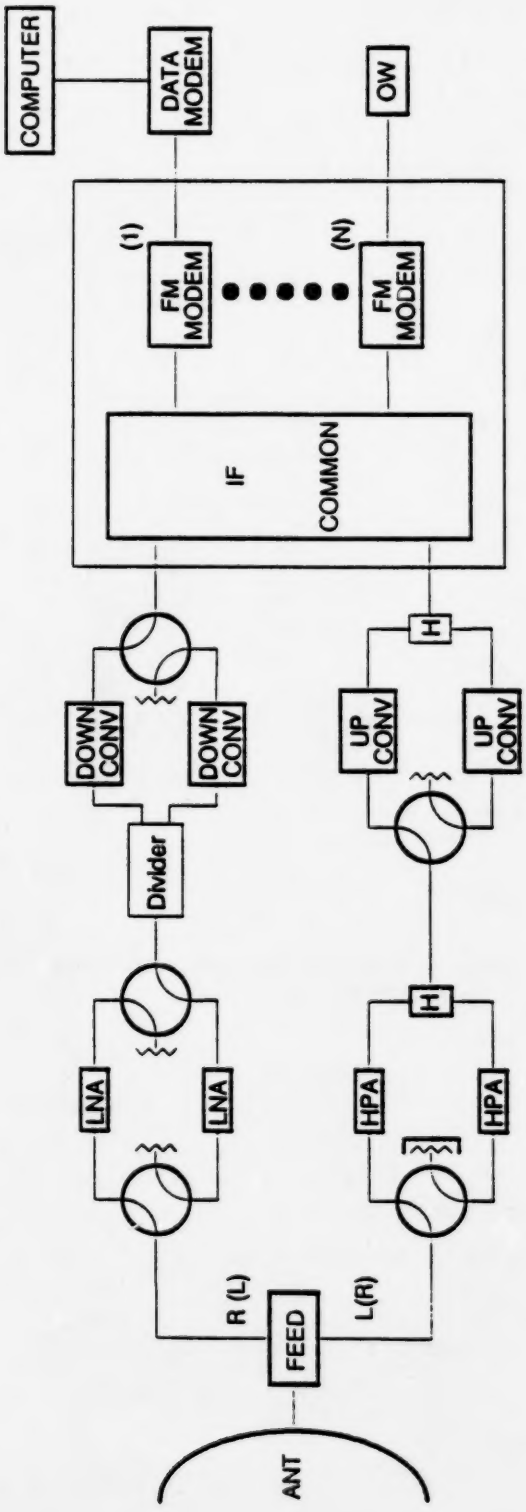
X . 25

Satellite protocol

DTE: Data Terminal Equipment

DCE: Data Circuit Terminating Equipment

Figure 5



System Block Diagram for SCPC Satellite Earth Station

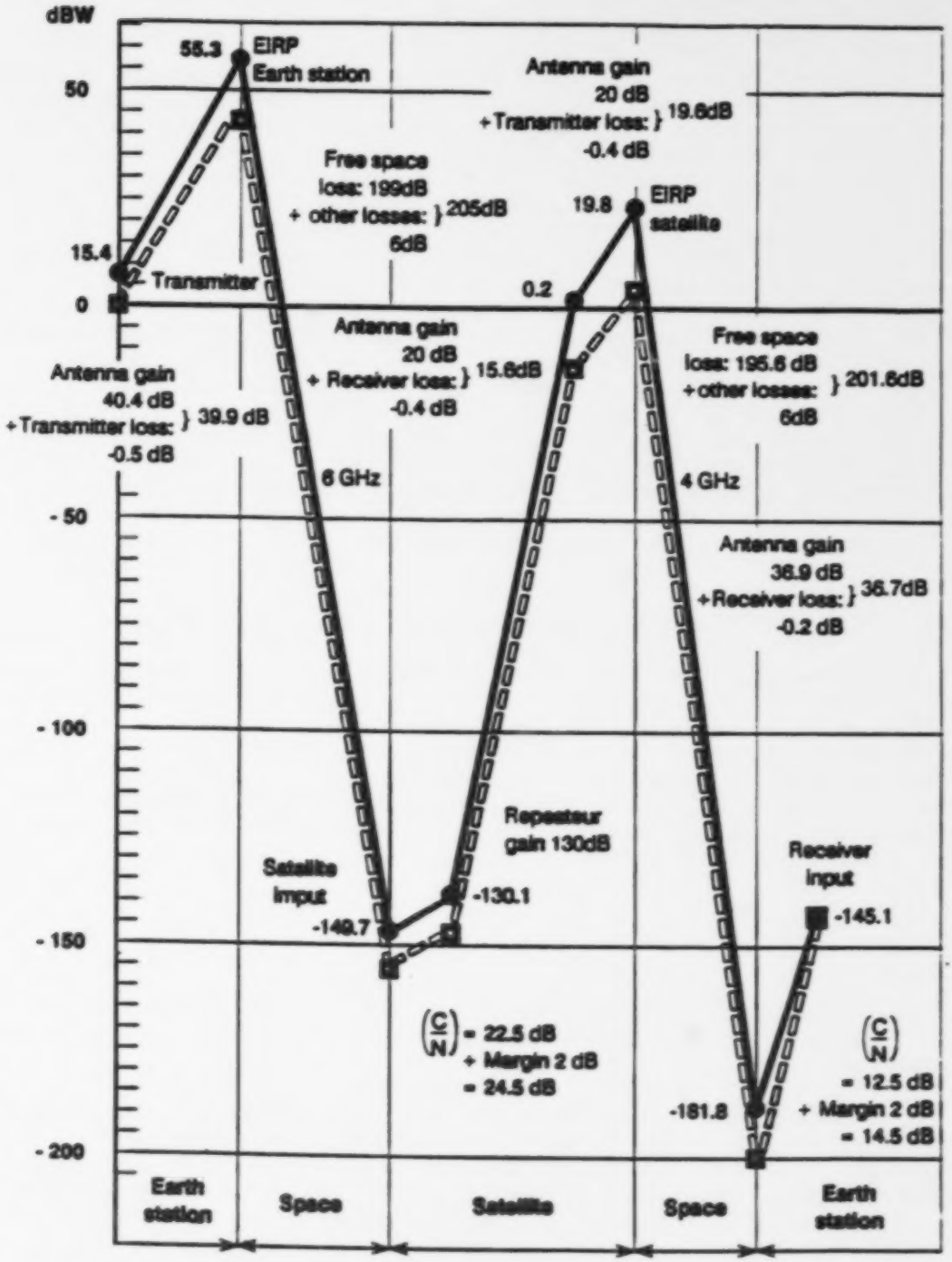
Figure 6

Small Earth Terminal

Figure 7

Central Hub Earth Station

Figure 8



Power levels in a
64 kbit/s SCPC satellite link . BER 10^{-4}

2 m Ø antenna to 2 m Ø antenna

2 m Ø antenna to 11 m Ø antenna

Figure 9

In a satellite link, the high performance of the one-end-terminal compensates for the modest performance of the other-end-terminal. For that reason the VSAT networks often adopt an architecture with a high performance hub station and small peripheral terminals. The latter usually cannot communicate direclty between them with an acceptable quality of transmission. However, they can communicate via the hub station (double hop). The longer time delay has no significant impact on the transmission quality but the error correction becomes more difficult because a large quantity of data has been transmitted before an error signal is received. Therefore, the satellite link budget must be arranged to give a low Bit Error Rate (BER), e.g., about 10-10 or less. When transmitted over a large intercontinental or regional satellite telecommunication system, data streams can also use the SCPC techniques, e.g., as used in the International Telecommunications Satellite Organization (INTELSAT) system. But in most cases the data links are transmitted as a part of larger digital carriers, either fixed-assigned ones called IDR carriers (Intermediate Data Rate) or TDMA (Time Division Multiple Access) carriers. These carriers generally contain both voice and data communications. Attention should be paid to ensure that the data channels are not going through the digital circuit multiplying equipment used for the voice circuits.

POSSIBLE USE OF TSDB SATELLITE TRANSMISSION

As already mentioned TSDB, satellite transmission could be used to give access to the ITU data banks to the ITU members who are the telecommunications authorities in the various countries of the world. It would also be possible for the members to modify or to update the data in the ITU banks. A project in that sense is envisaged but money is lacking for its realization. Consultations between TSDS could also be used bilaterally for checking and computing accounting settlements between two telecommunication administrations for the traffic exchange between them.

NOTES

1/ A protocol is a specification of the bit coding formats in which specific information is passed between processes, and also of the procedures to interpret it.

2/ Packet switching is the process by which information is exchanged between various DTEs in the form of data packets. This "packetized" information is routed dynamically, by so-called "virtual circuits", using a software process, from source to destination within a common communication network consisting of transmission lines of "packet switches".

SATELLITE COMMUNICATIONS AND DISASTER REFLIEF*

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INTRODUCTION

Although the mandate of United Nations Disaster Relief Co-ordinator (UNDRO) for disaster management is different from that for development, there is very often an overlap of both activities; and we are in the same position with regard to satellite communications because we are using the same, or almost the same, technology. UNDRO is the specialized office of the Secretary-General of the United Nations that is responsible for all disaster-related matters. One of its main functions is "to mobilize, direct and co-ordinate external assistance provided by the United Nations system in response to a disaster." UNDRO also promotes "pre-disaster planning as well as the study, prevention, control and prediction of natural disasters."

The subject of disaster mitigation and prevention is becoming all the more important as we realize how much loss of life and property is entailed by disasters each year and, on the other hand, how much could be saved by timely and appropriate action. Between 1967 and 1987, three million lives were lost. For that same period, property damage which was estimated at $23 billion was inflicted as a result of natural disasters that affected more than 829 million people. Early warning and the quick re-establishment of communications are vital to mitigation and relief operations alike, such as in earthquakes, floods, landslides, tsunamis, hurricanes, tornadoes, volcanic eruptions and wildfires.

The study of natural disasters, their prevention, control and prediction can benefit from new terrestrial and space technologies. These include mobile communications by satellite, cellular radio and remote-sensing technologies that will be "on-line" worldwide in the 1990s. Mitigation efforts for long-term hazards such as drought, locust invasions and desertification and man-made hazards such as ozone layer depletion can also be enhanced by these technologies.

LESSONS LEARNED

The following is an overview of UNDRO's experience and problems in disaster communications:

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* This paper, which was presented at the United Nations Workshop on Space Communications for Development, organized in co-operation with the Government of Cuba, Havana, 26-30 November 1990, does not necessarily reflect the views of the United Nations.

(a) Transmitting assessment and situation reports from disaster-stricken areas to UNDRO's headquarters at Geneva is often very dificult, especially from countries with damaged or non-operational communication systems. Other United Nations and international organizations are facing similar problems.

(b) With regard to recent, major natural disasters, it has again been established that reliable communication links between the affected area and the participants in disaster relief operations are a crucial factor in an effective and co-ordinated disaster response.

(c) In the past, reliable radio systems were difficult to use because of the high capital investment required, the necessary operational skills and even the weight of equipment. Over the last few years, however, rapid technical progress has been made in radio links by satellite.

(d) Satellite communication systems offer an important potential for real-time dissemination of disaster information. They have been used individually during recent disasters and have even been included in regional or national disaster management systems. However, an integrated global approach to this problem is lacking.

(e) There are also a number of significant issues which could limit the use of satellite communications such as the relatively expensive equipment, high operating costs (satellite time) and some legal disputes over individual countries' restrictions on the entry and exit of emergency communications equipment and relief personnel as well as on the permitted uses of satellite equipment.

The lessons learned in the Caribbean region also confirm the importance and, unfortunately, also the lack of communications during the first hours and even days after a disaster has occurred. Hurricane Hugo and Hurricane Gilbert in 1988 are recent examples.

Despite a well implemented disaster preparedness and prevention project, UNDRO had to report one day after Hurricane Hugo struck the region that all communications had been cut and that no detailed information on the damage, losses or needs was available. The first accounts were received later via the United Nations Amateur Radio Station. In the particular case of Hurricane Gilbert, the situation was even worse. Despite clear, severe weather warnings more than 48 hours before the onset of the event and the mobilization of all available means of communication, only ham radio was available for the first 72 hours.

An even worse communication situation occurred in 1985, when a damaging earthquake hit Mexico City. UNDRO's representative, who made a successful assessment immediately after the disaster occurred, was unable to transmit his report to UNDRO in Geneva for several days because of complete damage to the local communications structure.

The rapid development of communications technology sometimes causes completely different problems. In the case of the devastating earthquake in Armenia in 1988, over 15 radio satellite terminals were deployed in the region by various non-governmental and international organizations. Unfortunately, there was a lack of co-ordination. While some television stations and rescue teams could speak every hour to their headquarters abroad, UNDRO staff had no satellite communications equipment at its disposal and could not, for example, stop the French television appeal for blankets on the very same day that it was officially announced that blankets were no longer needed. The need to co-ordinate communications is made even greater by the fact that other Governments may not facilitate the deployment of communication means to the extent allowed in Armenia and may even drastically limit them.

CAN THE DEVASTATING EFFECTS OF NATURAL DISASTERS BE REDUCED?

Appropriate application of new and developing satellite telecommunications technologies can aid in the mitigation of the devastating effects of natural disasters. New low-cost mobile communications by satellite, for example, will play a major role in reducing the devastating effects of natural disasters and will complement and enhance existing terrestrial and fixed satellite services. It will dramatically improve hazard prediction, risk assessment, disaster preparedness, early warning and onset and post-disaster relief operations. This low-cost service will soon be available to areas previously considered impractical or impossible to cover because of their location, terrain, weather or demography.

Worldwide use of mobile satellite technology will bring several advantages. Among them are the following:

(a) Natural hazard mitigation experts in even remote areas can use newly developed small, simple and low-cost equipment;

(b) Emergency response and health care will be improved in areas and situations once considered impossible or impractical;

(c) Mobile satellite communications can be used by land, aeronautical and maritime transportation industries;

In addition, local, regional and worldwide communications for rural or underserved areas will be dramatically improved.

Recent space science technology has also created a dramatic improvement in our ability to measure and learn about the physical, chemical and biological interactions of the Earth's magnetosphere, atmosphere, oceans and land areas and to assess the importance of these interactions to global, physical and biogeochemical processes. Of course, these advantages of advanced space technology also play an important role in development activities.

INTERNATIONAL CO-OPERAITON

Today, the Earth is encircled at the equator by a set of geostationary meteorological satellites, including the United States' Geostationary Operational Environmental Satellites (GOES), the European Space Agency's (ESA) Meteosat, Japan's Geostationary Meteorological Satellite (GMS), and India's Indian National Satellite (INSAT). France, Japan and the Soviet Union have launched the low-altitude, polar-orbiting satellites SPOT, MOS-1 and Meteor respectively. The COSPAS/SARSAT search-and-rescue system is another example of international polar orbital activity. During the next few years, ocean- and land-observing satellites will be launched by Canada, France, Japan, India and ESA.

It is evident that international co-operation is indispensable to expand the applications of these new terrestrial and space technologies.

UNDRO's INTERNATIONAL CONFERENCE ON DISASTER COMMUNICATIONS GENEVA, 19-21 MARCH 1990

As part of its mandate, UNDRO has recently elaborated several projects in disaster communications, namely for the use of satellite radio terminals, and some of these projects are already being implemented. During 19-21 March 1990, UNDRO organized an International Conference on Disaster Communications, with the objective of bringing potential users of emergency satellite communications together with some producers and owners of these systems for an exchange of opinions and experience. Over 80 participants from 54 organizations identified major needs in disaster communications and approved a recommendation to UNDRO with a view to assisting those involved in disaster management. These recommendations are included in this article.

Altogether, there are 13 basic proposals in the present document, some of which are completely valid, particularly with regard to the use of space technology in terrestrial development activities. We are entering a period of transition. Cellular terrestrial and mobile satellite communications and remote sensing are passing from an experimental and limited operational phase to widespread availability and extensive operational use. The recommendations therefore concern some principal problems, such as the establishment of a centralized clearinghouse for the use of space communications and remote sensing, legal aspects, the procurement of portable radio satellite terminals for UNDRO staff and the availability and co-ordinated use of disaster communications by all participants in the field.

INTERNATIONAL DECADE FOR NATURAL DISASTER REDUCTION

The enormous loss of life and property caused by disasters has created a tremendous amount of national, regional and international solidarity and post-disaster assistance. However, the question has rightly been raised as to whether, and how, it will be possible for pre-emptive action to protect the world's population from such calamities.

It was with this idea in mind that the General Assembly of the United Nations, at its forty-fourth session, on 22 December 1989, adopted resolution 44/236 proclaiming the International Decade for Natural Disaster Reduction (IDNDR), which commenced on 1 January 1990. The importance of ensuring effective disaster communications has already been emphasized in the preparatory work leading to the Decade.

One of the objectives of UNDRO's International Conference on Disaster Communications was that all participants come to an overall understanding of the relevance of communications for disaster relief and mitigation and how best to use them. The Conference's conclusions and recommendations will have to be taken up also by the international mechanism for IDNDR, hopefully setting the path for an appropriate and timely development of high-standard communications systems in disaster-prone countries in line with the Decade's goals and objectives. The recommendations for disaster relief and the major needs identified for effective disaster relief communications are listed in appendices I and II.

Appendix I

RECOMMENDATIONS OF CONFERENCE PARTICIPANTS

UNDRO is the specialized office of the Secretary-General of the United Nations for all disaster-related matters. One of its main functions is "to mobilize, direct and co-ordinate external assistance provided by the United Nations system in response to a disaster." UNDRO also promotes pre-disaster planning as well as the study, prevention, control, and prediction of natural disasters."

UNDRO recognizes the importance of the vital role that communications and remote sensing technologies play in disaster relief, preparedness and prevention. UNDRO also stated that it intends to integrate and use these technologies more extensively in its disaster mitigation activities.

Consistent with UNDRO's mandate, and the needs identified on the preceding pages, the conference participants, by consensus, made the following recommendations.

UNDRO, with the support and co-operation of the International Decade for Natural Disaster Reduction (IDNDR) framework, should:

(a) Take the leadership role in obtaining international agreements facilitating entry and exit and operations of communications equipment by relief teams in stricken countries.

(b) Promote international agreements on the use of appropriate terrestrial and satellite frequencies and services for disaster operations in co-operation with the International Telecommunication Union (ITU), as required.

(c) Identify criteria for priority access to communications frequencies for emergency use, and obtain agreements on priority access procedures.

(d) Contribute within the framework of the International Decade for Natural Disaster Reduction (IDNDR), to ensuring that the benefits of disaster communications and remote sensing technologies are made available to countries so that they can develop or improve their own disaster-resistant communications infrastructure and, ultimately, manage their own mitigation efforts.

(e) Develop, maintain, and update, in co-operation with the entities concerned, a centralized clearinghouse for the collection and dissemination of accurate and timely information about telecommunications and remote sensing technology applicable to disaster management, including an inventory of parameters and availability of equipment in countries at risk and from other countries and institutions engaged in disaster relief operations.

(f) Facilitate and expand the training of disaster management personnel in the use of telecommunications and remote sensing technologies.

(g) Establish the information networking necessary to ensure that accurate information, including damage and casualty assessment, is disseminated in a timely manner.

(h) Support local efforts to ensure that an effective interface exists between a country's internal communications and its communications with other countries and institutions involved in disaster relief operations. This would then enable the effective co-ordination and dissemination of information concerned with disaster relief operations.

(i) Develop its own in-house technical resources to provide, within hours, essential telecommunications capability in support of disaster relief operations.

(j) Negotiate with domestic and international communications carriers for a more favourable tariff structure than presently exists for communications capacity during response efforts to major disasters.

(k) Develop a philosophy and an approach to payment for communications services required in disaster management efforts.

(l) Encourage countries to inventory their satellite and terrestrial telecommunications hardware to establish their availability for disaster management purposes.

(m) Request ITU's assistance, where applicable, in establishing the process for protocols and standards for disaster communications operations and in other areas of ITU's competence.

Representatives of the international amateur radio community offered their services to UNDRO in the event that all communications were lost in the affected areas and until UNDRO established its own communications.

The need for substantive financial resources for the implementation of the outlined recommendations was acknowledged. In line with the resolution on IDNDR, the conference participants urged that the international community, including Governments, donor organizations, the private sector and other sources make the necessary funds available.

Appendix II

MAJOR NEEDS IDENTIFIED BY THE CONFERENCE PARTICIPANTS

The following are the major needs that have been identified for effective disaster relief communications:

(a) Establish international agreements facilitating entry and exit and operation of communications equipment by relief teams in stricken countries.

(b) Establish international agreements on appropriate frequencies for disaster operations.

(c) Involve ITU, where applicable, in establishing the process for protocols and standards for disaster communications operations.

(d) Identify criteria for priority access to communication frequencies for emergency use, and obtain agreements on priority access procedures.

(e) Reduce the vulnerability of existing telecommunications infrastructures.

(f) Ensure that the benefits of disaster communications and remote sensing technologies are made available to countries so that they can develop or improve their own disaster communications infrastructure and, ultimately, manage their own mitigation efforts.

(g) Develop links between search and rescue teams from different countries by a common network.

(h) Provide telecommunications facilities to ensure timely and accurate information, including damage and casualty assessments.

(i) Develop approaches to offloading non-emergency traffic from the emergency network.

(j) Negotiate with domestic and international communications carriers for a more favourable tariff structure than presently exists.

(k) Develop a philosophy and an approach to payment for communications services required in disaster management efforts.

(l) Devote greater attention than presently given to use of telecommunications and remote sensing technologies in disaster prevention and preparedness.

(m) Develop, maintain, and update a centralized clearinghouse for the collection and dissemination of accurate and timely information about telecommunications and remote sensing technology and its application to disaster management.

(n) Establish an inventory of parameters and availability of equipment in countries at risk and from other countries and institutions engaged in disaster relief operations.

(o) Acquisition and operation of disaster communications and remote sensing resources should be planned for, and provided, on a priority basis in the same context as other high priority relief supplies.

(p) Develop a process for training disaster mitigation personnel in the use of maintenance of telecommunications and remote sensing technologies.

(q) Encourage countries to inventory their satellite and terrestrial telecommunications and remote sensing hardware to establish their availability for disaster management purposes.

(r) Develop options for reconstitution, within hours, of essential telecommunications capability.

(s) Identify options for short-distance communications equipment within a stricken area.

(t) Develop the capability to deploy disaster communications equipment within a stricken area within 12 hours.

(u) Ensure that an effective interface exists between a country's internal communications and its communications with other countries and institutions involved in disaster relief operations.

(v) Ensure adequate and reliable power sources for telecommunications equipment.

(w) Ensure that countries which often lack adequate disaster communications infrastructure have access to communication. Therefore, UNDRO should acquire and maintain its own mobile or portable terminals for its disaster relief operations, and possibly, for use by the stricken country.